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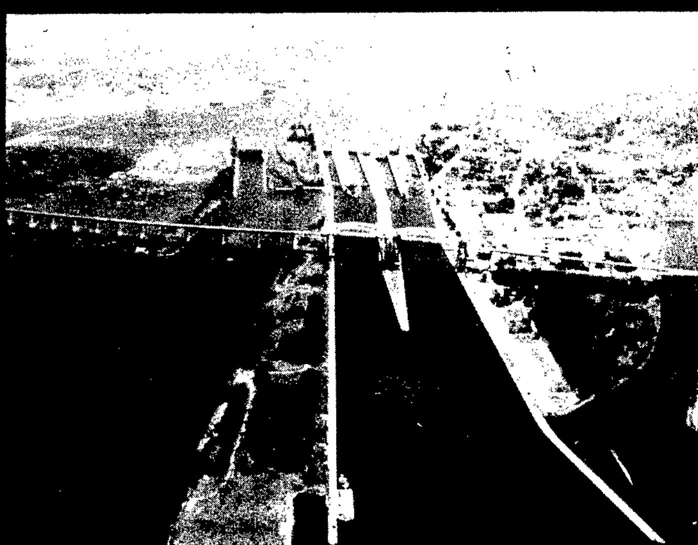
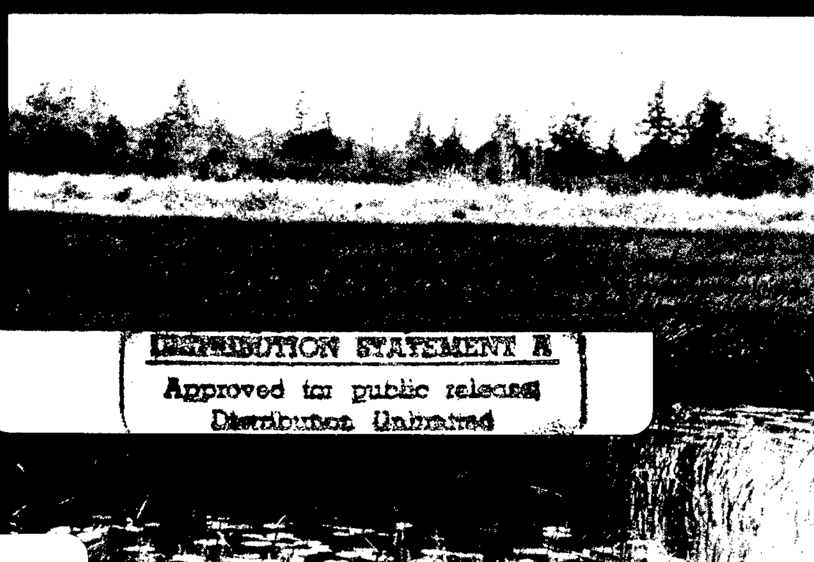
May 1987



THE ST. MARYS RIVER, MICHIGAN: AN ECOLOGICAL PROFILE



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Cover:

Top--Aerial view (looking east) of the St. Marys Rapids. Sault Ste. Marie, Ontario, is on the left; Sault Ste. Marie, Michigan, on the right. Photo courtesy of Clarence D. McNabb.

Bottom Left--Aerial view of a 305-m long iron-ore carrier, sailing south through the Nicolet reach of the St. Marys River. Photo courtesy of Clarence D. McNabb.

Bottom Right--West Nicolet wetland complex, Michigan. Predominant emergent vegetation in the foreground is _Sparganium eurycarpum_ (bur reed); trees in the background are _Picea marina_ (black spruce). Photo courtesy of Walter G. Duffy.

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THE ST. MARYS RIVER, MICHIGAN: AN ECOLOGICAL PROFILE

by

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PREFACE

This monograph on the ecology of the St. Marys River is one of a series of U.S. Fish and Wildlife Service profiles concerning important coastal ecosystems of the United States. The purpose of this profile is to synthesize the literature available for the St. Marys River and to describe the ecological structure and functioning of the river. The St. Marys River is the sole outlet from Lake Superior--an oligotrophic lake containing one-tenth of the world's surface water--and forms a connecting channel to Lake Huron. Although relatively short in length, the river is unique in having an immense drainage basin consisting of both an immediate basin and the drainage basin of Lake Superior. The large volume of oligotrophic water passing through the river from Lake Superior influences the physical and chemical nature of the river's water and its biological communities.

The St. Marys River historically supported an important subsistence fishery and continues to provide a valuable sport fishery while also serving as a major transportation link between north-central and northeastern North America. While development along the river is limited, human activities associated with shipping and industry have physically altered the ecosystem and resulted in at least localized contamination.

This profile is intended to provide a useful reference to the scientific information available for the St. Marys River. The profile includes a description of the general setting, geologic history, and human settlement of the area (Chapter 1), and a detailed description of the river's physical and chemical characteristics (Chapter 2). The biological communities of the river are described (Chapter 3) and ecological relationships discussed (Chapter 4) prior to a discussion of management considerations (Chapter 5).

Any questions or comments about or requests for this publication should be directed to:

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
nanometers (nm)	0.3937×10^{-8}	inches
micrometer (µm)	0.3937×10^{-5}	inches
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (L)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (mt)	2205.0	pounds
metric tons (mt)	1.102	short tons
kilocalories (kcal)	3.968	Btu
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms (fm)	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556(°F - 32)	Celsius degrees

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ACKNOWLEDGMENTS

A literature synthesis such as this profile is developed from the work of many researchers. Space limitations prevent us from covering some topics in the detail they deserve. However, we hope that our interpretation and summary of data presented by others reflect their original conclusions. Much of the data used in writing this profile were gathered by students, faculty, and staff of the Department of Fisheries and Wildlife, Michigan State University. Our own research and observations made while on the river have also influenced the writing of this profile. The preparation of this publication has been sponsored by the Great Lakes National Program Office of the U.S. Environmental Protection Agency, and the National Wetlands Research Center of the U.S. Fish and Wildlife Service.

Natural resource agencies from the State of Michigan and Province of Ontario shared unpublished data from the river, enabling us to treat certain topics which could not have been discussed otherwise. Tom Weise (Michigan Department Of Natural Resources) and Evan Thomas (Ontario Ministry of Natural Resources) were very generous with unpublished information.

Colleagues who reviewed earlier drafts include David Behmer (Lake Superior State College), Paul Bertram (U.S. Environmental Protection Agency), Richard Greenwood, Edward Pendleton, and Larry Sisk (U.S. Fish and Wildlife Service), Joseph Leach and D.M. Whittle (Ontario Ministry of Natural Resources), and Asa Wright (Michigan Department of Natural Resources). We appreciate the comments and constructive criticism offered by each and share their interest in the river. Rob Brown and Dana Criswell (U.S. Fish and Wildlife Service) provided editorial assistance. Their comments often provided clarity where none seemed possible. Sue Lauritzen assisted in drafting many of the figures and Anita McKelroy, Joyce Rodberg, and Daisy Singleton assisted in word processing.

CHAPTER 1. INTRODUCTION (GEOLOGICAL AND HISTORICAL ASPECTS)

ST. MARYS RIVER AS A NATURAL UNIT

The St. Marys River is a former strait which connects Lakes Superior and Huron. The most northern of the Great Lakes connecting channels, it originates from Whitefish Bay in Lake Superior between Point Iroquois, Michigan, and Gros Cap, Ontario. It flows in a southeasterly direction approximately 112 km before emptying into Lake Huron at De Tour, Michigan (Figure 1). The river falls about 6.7 m between its headwaters and mouth; however, 6.1 m of this drop in elevation occurs at the St. Marys Rapids, 23 km below the headwaters. The river is bounded on the south and west by the Upper Peninsula of Michigan: on the north and northeast by the Ontario mainland; and on the east, first by St. Joseph Island, Ontario, and then by Drummond Island, Michigan, which forms the most southerly border.

A number of small- to medium-sized rivers drain the area adjacent to St. Marys River to form the immediate drainage basin, much of which lies over the southern edge of the Precambrian (or Canadian) shield (Figure 2). The river itself is unique in that it is relatively short in length, yet has a large drainage basin. The basin's large size is due to the fact that the river is the only outflow from Lake Superior with its drainage basin of 21,000 km^2 (39% of this is covered by the lake; International Joint Commission [IJC] 1976). The volume of oligotrophic water in Lake Superior is approximately 12,000 $\pm$ 200 km^3 --roughly one-tenth of all the world's surface water (Matheson and Munawar 1978). About 95% of the land surface of both basins is covered by forests. An important ecological consideration is that the water which drains from the immediate watershed is a mere fraction of that which flows out of Lake Superior.

The surficial geology of the southwestern St. Marys River Valley is primarily lacustrine sediments and moraines (Figure 3). On the southwestern edge of the valley in Michigan, level lakebed plains are interrupted by gently rolling plateaus, low rounded ridges, or lakeshore features such as remnant beach ridges, sand dunes, bluffs, or marshland (Veatch et al. 1927). In Ontario, on the northeastern edge of the valley, knobby Precambrian rock is partially covered by a thin layer of till or lacustrine clay (McCuthcheon 1968). Numerous lakes also dot the Precambrian shield area north of the river. Mineral soils in the vicinity of the river are comprised of clays, loams, or sands (Table 1). These soils, in general, are highly retentive of water as are the organic soils common west and south of Munuscong Lake.

Water currents of the river are highly variable and are influenced mainly by discharge to the river from Lake Superior and water-surface elevation at Lake Huron. Current velocities are impeded by high surface-water levels in the river's mouth at Lake Huron brought about by easterly or southerly winds or low barometric pressure. On the other hand, high surface-water levels in Lake Superior result in greater discharge to the river and increased current velocities; however, discharge to the river has been controlled by compensating gates since 1921. Surface currents are also influenced by winds, particularly in broad expanses of the river. The passage of commercial vessels temporarily alters both surface and subsurface water currents as well.

Hydrologically, the St. Marys River may be divided into three major reaches: (1) the upper river extending from Whitefish Bay, Lake Superior, to the St. Marys Rapids, (2) the rapids, and (3) the lower river extending from the foot of the

rapids to De Tour Passage at Lake Huron. The upper river, 22.5 km long, decreases in width rapidly and is characterized by sandy or rocky shores, with emergent wetlands occurring only in protected areas. The rapids separating the upper and lower river is an area 1.2 km long and 1.6 km wide, where the river drops 6.1 m. Substrate in the rapids consists of boulders 1.0 m or more in diameter and exposed bedrock. The topography of the upper river and rapids is more pronounced than that of the lower river, rising to a maximum elevation about 200 m above the river on the north. South of the river, elevation rises abruptly to about 30 m above the water level, then grades into a gently rolling broad plain.

The lower river has a very irregular shoreline and contains four large islands: Sugar, Neebish, and Drummond on the American side, and St. Joseph on the Canadian side, as well as more than 100 smaller

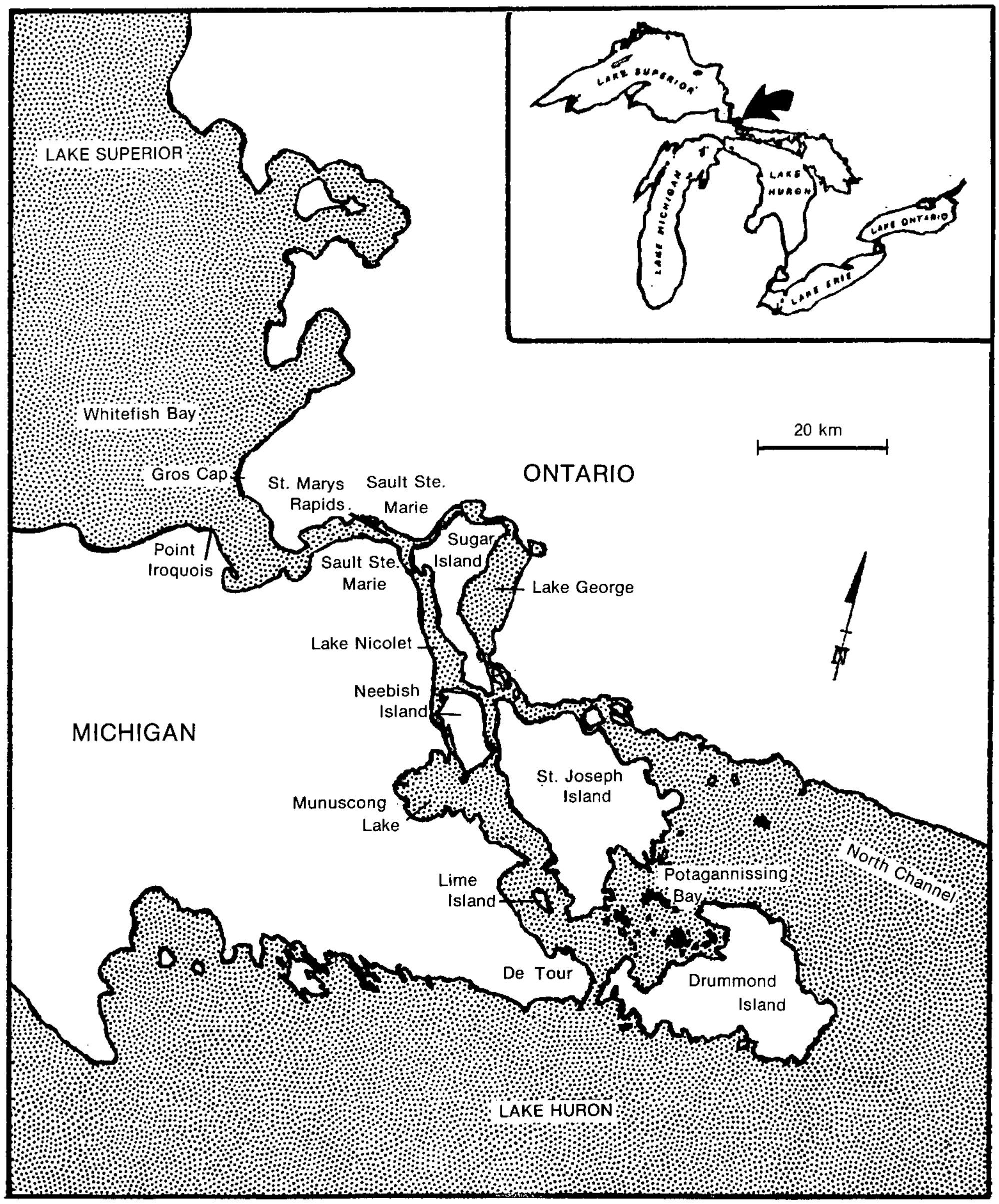
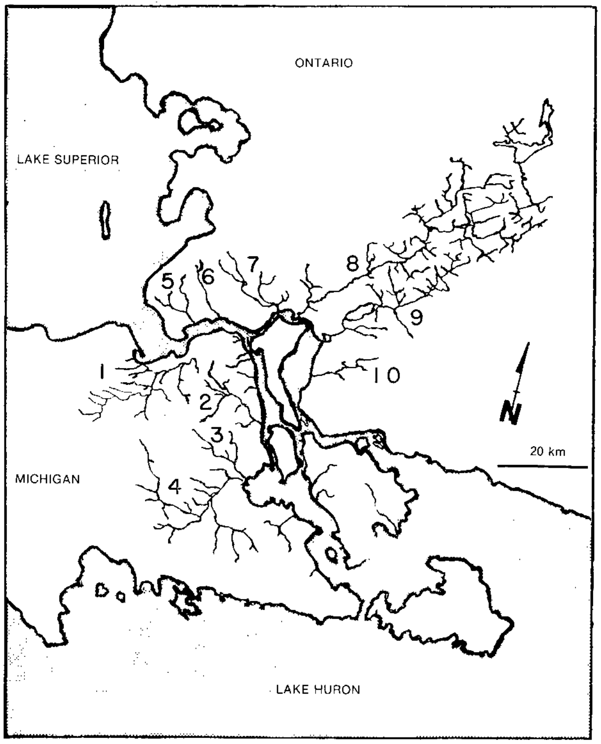
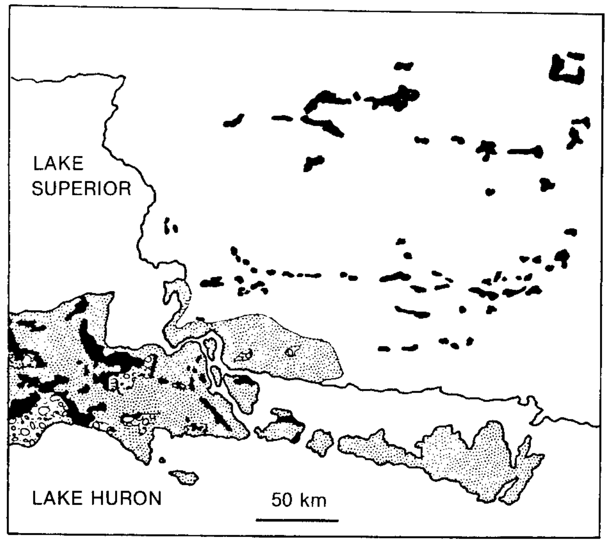


Figure 1. Location map of the St. Marys River and vicinity.



1	Waiska River	6	Bennet Creek
2	Charlotte River	7	Root River
3	Little Munuscong River	8	Garden River
4	Munuscong River	9	Echo River
5	Big Carp River	10	Bar River

Figure 2. Watershed map of the St. Marys River.



KEY

Lake sediments

Ground moraines and outwash plains

Wisconsin end moraines

Thin till over moderately rolling bedrock

Figure 3. Surficial geology of eastern upper Michigan and northeastern Ontario.

islands <4 km^2 in area (Table 2). Sugar island is 24 km long, has a maximum width of 13 km, and is oriented north to south. It separates the Lake George and Lake Nicolet reaches of the river immediately below the rapids. Approximately 74% of the river's flow courses through the Lake Nicolet reach while the remaining 26% flows through Lake George (Liston et al. 1986). Both lakes are broad expanses in the river which empty into channels formed by St. Joseph and Neebish Islands and the Michigan mainland. Below Neebish Island these channels discharge into Munuscong Bay, where the river widens and flows southeasterly before discharging into Lake Huron between Drummond Island and the Michigan mainland. The lower river is bordered on the west by extensive areas of emergent wetlands which grade into forested or palustrine wetlands as defined by Cowardin et al. (1979). Chippewa County, Michigan, borders the river with 4,848 ha of coastal wetlands (Jaworski and Raphael 1978). On the river's east border, relief is greater and palustrine wetlands are generally restricted to tributary mouths. The eastern shore consists of unconsolidated or rocky shores in exposed reaches, with emergent wetlands occupying more protected areas.

GEOLOGY

Preglacial History

The present configuration of the Great Lakes Basin is primarily the result of glaciation during the Pleistocene epoch

Table 1. Predominant soil types in eastern Chippewa County, Michigan, on islands within or lands adjacent the St. Marys River (Veatch et al. 1927).

Soil Type	Location						
	West Lake Nicolet	Sugar Island	Neebish Island	Sand Island	Munuscong Lake Area	De Tour Area	Drummond Island
Bergland silty clay loam	x		x		x		
Bruce fine sand loam	x				x		
Blue Lake sandy loam (stoney phase)					x		
Coastal beach	x	x	x	x	x	x	x
Carbondale muck					x		x
Detour stoney loam						x	x
Eastport sand						x	
Grandby sand						x	
Johnswood stoney loam							x
Munising stoney loam	x	x					
Munising stoney sandy loam	x	x	x				
Newton sand				x			
Ontonagon clay							x
Ontonagon silty clay loam	x	x	x				
Rock outcrops			x			x	x
Spaulding peat					x		
Strongs loamy sand					x		
Tahquamenon peat				x			

Table 2. Areas of the five largest islands in the St. Marys River.

Island	Area (km^2)
St. Joseph	596
Drummond	311
Sugar	117
Neebish	52
Lime	4

approximately 10 thousand to 1 million years ago. The five Great Lakes basins were covered with ice until 10-14 thousand years ago and are relatively young in geologic time. Despite this relatively young age and the influence of glacial activity on reshaping surface topography, events of earlier geologic history have some bearing on basin formation and present lake conditions.

The Precambrian era, which ended about 600 million years before the present (YBP), was a period of intensive volcanic and tectonic activity in the Upper Great Lakes area. The northern Great Lakes area--what is now central Canada and the north-central United States--was formed 1.9 to 2.0 billion YBP by the collision of smaller pieces of continents (Kerr 1985). Volcanic and tectonic activity and subsequent compression formed the igneous and metamorphic rocks of the region. Though the continent was formed roughly 2 billion YBP, some rocks from the Canadian shield have been dated to 3.5 billion YBP (Dorr and Eschman 1970).

Rocks formed during periods of volcanic activity were later intermittently

reworked through crustal deformation and igneous intrusion during several orogenies (mountain-building episodes) in Precambrian time. One such mountain range, known as the "Northern Michigan Highlands," extended from the Upper Peninsula of Michigan across the St. Marys River Basin into Ontario (Figure 4). Material eroded from this mountain range, along with Canadian shield rock, forms the parent materials of the Lake Superior watershed and basin (Figure 5).

During most of the Paleozoic era, shallow seas inundated much of the North American interior, including Michigan, portions of Ontario, and the entire St. Marys River Basin (Hough 1958, 1963). During the early Ordovician period, these seas temporarily retreated from the northern Great Lakes area, including the St. Marys River Basin, only to readvance over the entire Michigan basin until later in the Paleozoic era. Sediments which accumulated on these sea floors eventually formed the relatively resistant dolomite rock formations of the Great Lakes area.

Dolomite formed during the Silurian period of the Paleozoic era has an obvious influence on the Great Lakes Basin (Hough 1958). Silurian-aged dolomite encircles Lakes Michigan and Huron, then extends between Lakes Erie and Ontario into New York State to form the Niagara Escarpment over which the Niagara River drops to form Niagara Falls. The Door Peninsula separating Green Bay from Lake Michigan, the Saugeen Peninsula separating southern Georgian Bay from Lake Huron, and the islands of northern Lake Huron are all also formed from Niagaran Dolomite. In the St. Marys River system, St. Joseph and Drummond Islands were formed from the same rock formation. This relatively resistant dolomite, in general, forms the higher elevation portions of the Great Lakes Basin. Less resistant shales and slates formed in the late Paleozoic era when inland seas were retreating are found in the lower elevations of the Great Lakes Basin.

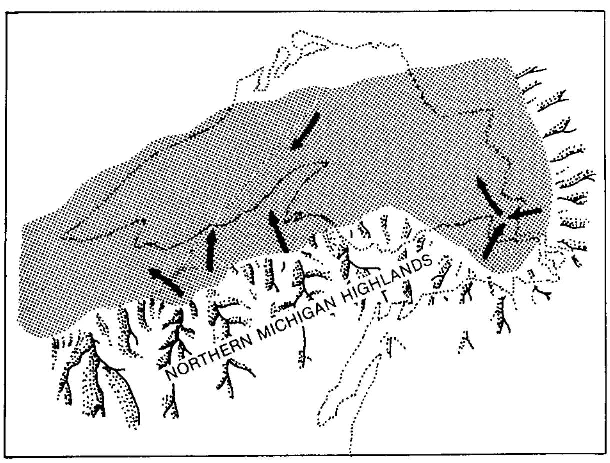


Figure 4. Paleogeography of the latest Precambrian time in Michigan, illustrating drainage from remnant mountains (Dorr and Eschman 1970).

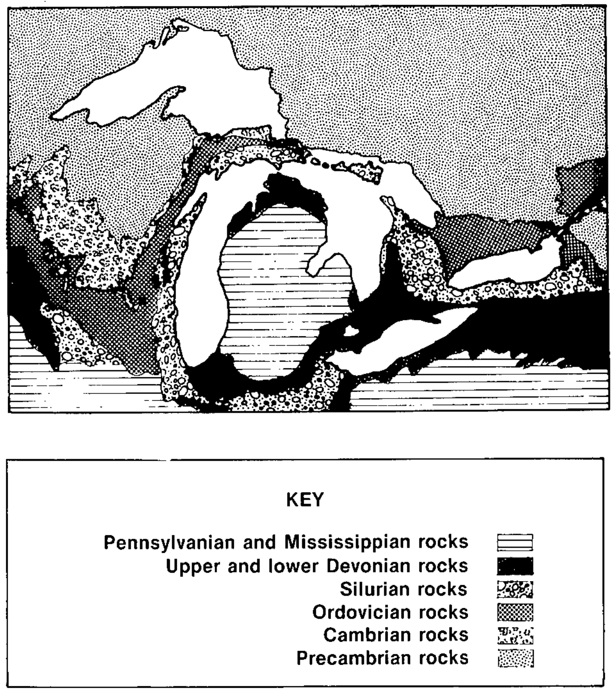


Figure 5. Rock strata of the Great Lakes region (modified from Upchurch 1976).

Dolomite deposits of the Great Lakes area contain a variety of fossil fishes and marine invertebrates which are indicative of warm, well-oxygenated inland seas. Fossil remains recovered within the St. Marys River Basin are predominantly marine invertebrates (Table 3). However, a number of marine vertebrates associated with the Silurian seas have been collected

Table 3. Number or presence (x) of fossil taxa from the Devonian period collected at four sites in the St. Marys River (Dorr and Eschman 1970).

	Site			
Taxa	West Neebish Channel	St. Joseph Island	Lime Island	Drummond[a] Island
Trilobites	5	4		x
Cephalopods	1	2	x	x
Scyphozoans	1			x
Brachiopods	11	5	x	x
Bryozoans	6	2		x
Corals	2	2	x	x
Pelecypods		4		x
Gastropods		5		x
Stromatapods			x	x

[a]Quarries on Drummond Island are rich in upper Devonian fauna and presumably contain all or most of the taxa listed (Dorr and Eschman 1970).

nearby; these include walrus from nearby Mackinac Island and bowhead whale from northern lower Michigan.

Following the Paleozoic era and the retreat of seas from the midcontinent region, a period of erosion began which lasted throughout the Mesozoic and Cenozoic eras until the Pleistocene epoch (approximately 200 million years). Erosion over such a long period created a system of valleys whose axes were aligned along belts of weaker rock (Dorr and Eschman 1970). These stream valleys formed the drainage pattern of the midcontinent region and were the eventual sites of the present Great Lakes basins (Figure 6).

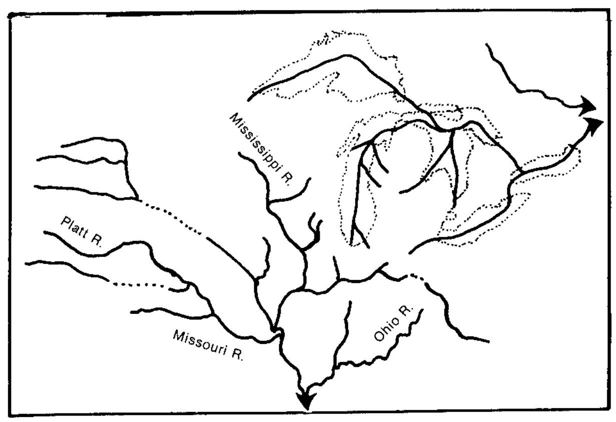


Figure 6. Preglacial drainage pattern of the Great Lakes region (Hough 1958).

Wisconsinan Glacial History

Subsequent to the development of the pre-Pleistocene drainage system, continental glacial ice invaded the Great Lakes region in four major stages beginning about 1 million YBP (Table 4). The flow of ice was guided by major topographic features, with deeper ice forming in existing stream valleys and scouring them further (Hough 1963). The basins of the Great Lakes were thus formed by stream erosion and glacial scour.

The first lakes that can be established as existing in the Great Lakes basins were formed only about 14,000 YBP, although earlier lakes probably occupied the region during interglacial periods. Each glacial advance, however, destroyed geologic evidence of these lakes such as beaches, shore terraces, shoreline deposits, and erosional features. As a result, the most complete record comes from the Wisconsinan series of the Pleistocene epoch dating from 50,000 to 10,000 YBP.

During the Wisconsinan glacial period, ice extended over the entire Great Lakes region. As glacial ice began to retreat, existing lake basins were gradually

Table 4. Approximate geologic time scale relating to the evolution of the Great Lakes (Dorr and Eschman 1970).

Era	Period	Epoch	Series	Start of period (YBP)
Precambrian				3.5 billion
Paleozoic				600 million
Mesozoic				190 million
Cenozoic				
	Tertiary			60 million
	Quaternary			
		Pleistocene		
			Nebraskan	1 million
			Kansan	700 thousand
			Illionian	300 thousand
			Wisconsinan	50 thousand
			Periglacial & Algonquin (substage)	14 thousand
		Holocene[a]		
			Max. lake isolation	10.6 thousand
			Broad lake connections	8.1 thousand
			Modern lake configuration & altithermal	6 thousand

[a]See text for description of series in Holocene.

uncovered and filled with water from glacial melt and normal runoff. With continued retreat, a series of proglacial lakes were formed behind glaciers held in by ice dams in the north and by higher ground in the south (Figure 7A-F). Early proglacial lakes initially occupied only the southern Great Lakes Basin (Figure 7A). As glacial retreat continued, greater areas of lake basins were exposed and pressure on the Earth's surface created by hundreds of meters of ice was gradually alleviated (Dorr and Eschman 1970). This allowed the Earth's surface, which had been compacted by the weight of ice, to rebound upward. Crustal rebound and the resulting uplift closed off former lake outlets and altered drainage patterns; at the same time, new outlets were opened by the retreating glaciers (Figure 7B). These processes continued over thousands of years and caused lake-surface levels to fluctuate from <150 m to >334 m above present sea level.

The earliest known lakes of the Superior basin that directly affected the St. Marys River Valley came into existence several thousand years after Lakes Chicago and Maumee (Figure 7A; Hough 1963). The Superior basin was occupied by Lake Keweenaw about 12,700 YBP. At this time, ice had retreated to the southern portion of the St. Marys River Valley (Figure 7C). Glaciers subsequently readvanced over the area, then again retreated, uncovering the St. Marys Valley about 11,000 YBP (Figures 7D and 7E; Saarnisto 1974). With the deglaciation of the Superior basin, discharge was directed through the St. Marys Valley and the St. Marys River was formed (Figure 7F).

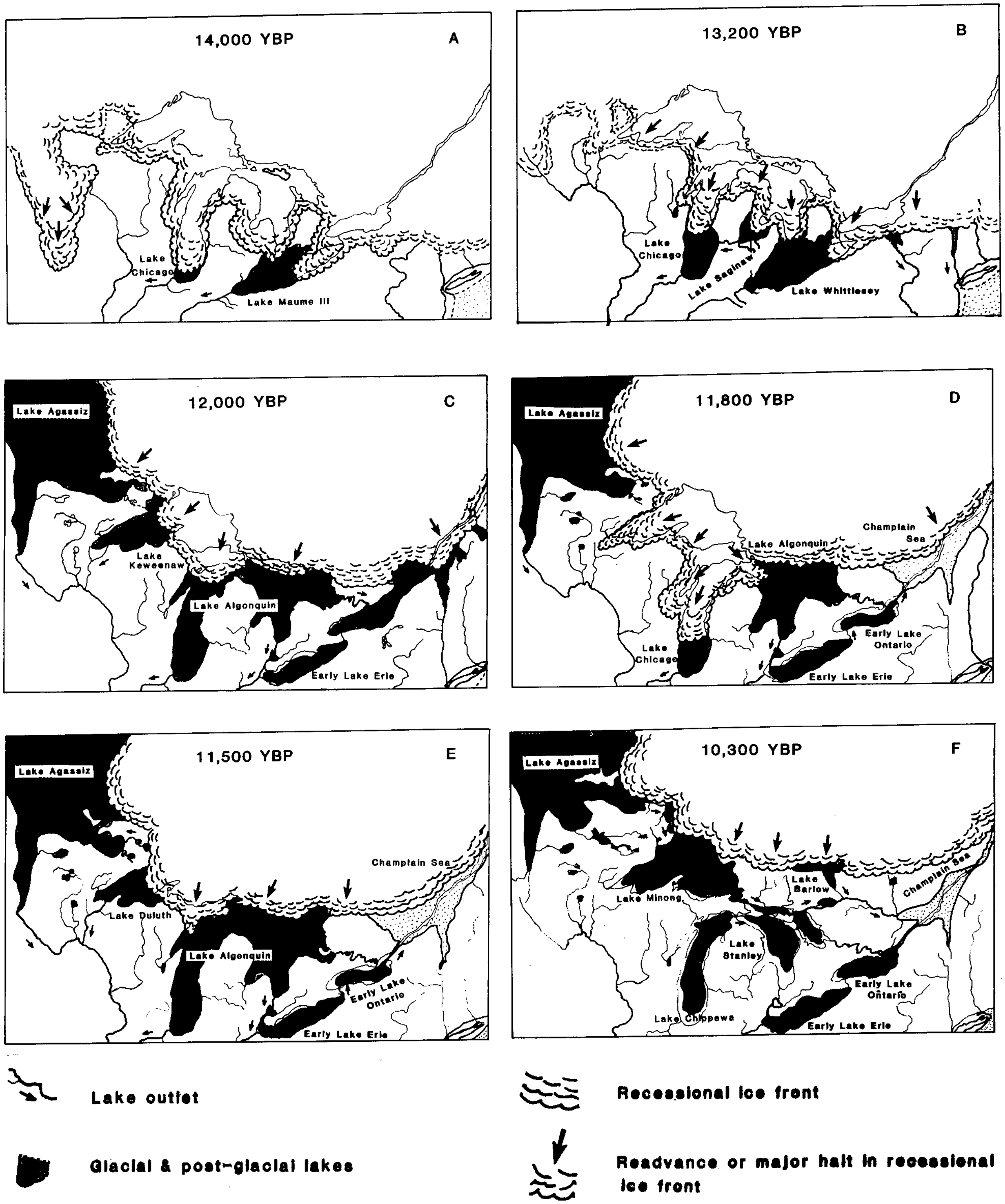


Figure 7. Pleistocene glaciation of the Great Lakes region from 14,000 to 10,300 years before present (YBP) (modified from Bailey and Smith 1981).

Postglacial History

Geologic structures underlying the St. Marys River Valley, built over billions of years, and surface features, scoured during Pleistocene glaciation, have changed little since 11,000-10,000 YBP. Much of the bedrock of the river basin consists of resistant sandstones, volcanic, and granitic rocks of Precambrian origin in the north and Ordovician-aged dolomites in the south (Figure 8). The primary influence on the surficial geology of the St. Marys River Basin during the Holocene was fluctuating water level.

Water levels in the Great Lakes rose to >334 m above sea level 11,200 YBP as glacial meltwater fed proglacial Lake Agassiz and the Superior basin and both drained southeast through the St. Marys Valley (Figure 7F). At this time the St. Marys River was probably a strait connecting Lakes Superior and Huron. However, glacial retreat opened a new outlet at North Bay, in Lake Huron, and by 10,600 YBP lake levels had declined so that only fluvial connections existed

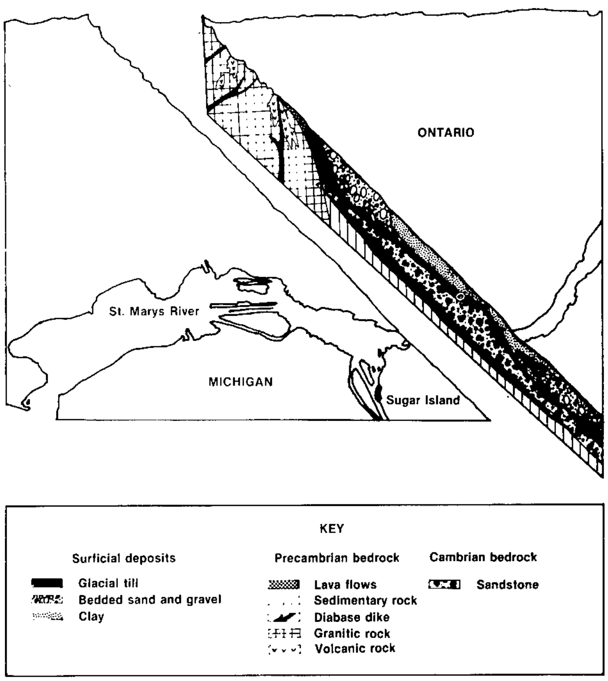


Figure 8. Cross-section of the geology of Sault Ste. Marie and vicinity (modified from Hunter and Associates 1979).

between the Upper Great Lakes (Bailey and Smith 1981). Another period of high water levels occurred 8,100-6,000 YBP as crustal rebound closed drainage outlets, but quickly receded as new outlets were opened. Then, as recently as 3,000 YBP, crustal rebound uplifted rock ledges at Sault Ste. Marie to a level higher than the water level of Lake Huron (Moore 1948). This transformed the strait connecting Lakes Superior and Huron into the St. Marys River.

Present lake levels have varied relatively little during the past 4,000 years. Historically, fluctuating water levels eroded surface deposits in the St. Marys Valley, leaving remnant beaches, sand dunes, and other littoral features in their place (Boissonneau 1968). Lacustrine-deposited clays now comprise much of the area's soils south of the Canadian shield.

Early Flora and Fauna

As the glacial ice front retreated from the St. Marys River region, tundra vegetation soon became established in the area. Pollen cores taken from Twin Lake northeast of Sault Ste. Marie, Ontario, indicate that tundra vegetation predominated in the area from 10,650 to a little before 10,000 YBP (Saarnisto 1974). Characteristic plants of the area at this time included sedges (Cyperaceae), sagewort (*Artemisia* sp.), ragweed (*Ambrosia* sp.), willow (*Salix* sp.), and green alder (*Alnus crispa*). Spruce (*Picea* sp.) forests, with associated red pine (*Pinus resinosa*) and jack pine (*P. banksiana*), succeeded tundra vegetation (Figure 9). The spruce forest gradually gave way to birch (*Betula* sp.) forests which also contained red and jack pine, alder, fir (*Abies* sp.), and sweet gale (*Myrica* sp.). The birch forest finally succeeded to pine forests comprised of red, jack, and white pine (*P. strobus*).

With retreat of the glaciers and the establishment of vegetation in the region, animal communities became established, changing in composition with the changing forests (Figure 10). Evidence from other parts of the Great Lakes region suggests that the earliest vertebrate mammal most

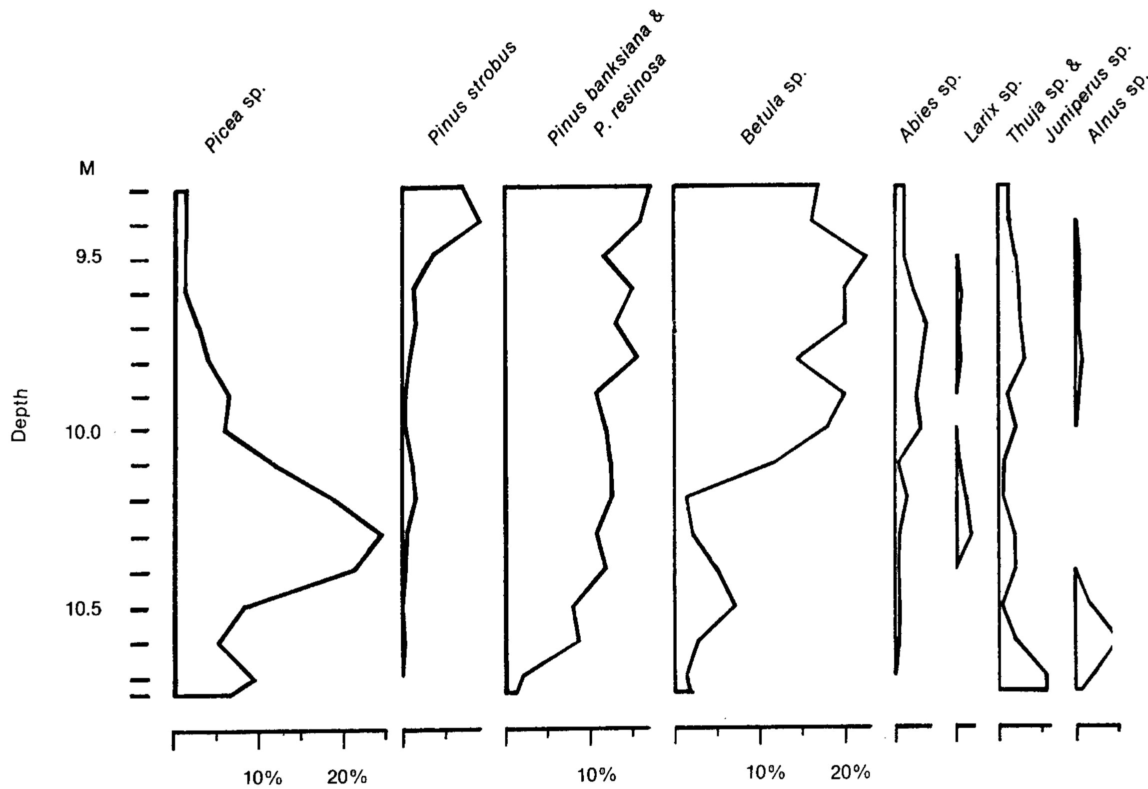


Figure 9. Pollen profiles for sediments from Upper Twin Lake, near the head of the St. Marys River (Boissonneau 1968).

likely to have inhabited the St. Marys Valley may have been the woodland musk ox (Symbos cavifrons), which followed the retreating glaciers north (Dorr and Eschman 1970). As forests became well established in the area, other mammals which likely invaded from southern Michigan and Ontario were the now extinct Scott's moose (Cervalces), giant beaver (Castoroides ohioensis), and woodland caribou (Rangifer tarantus caribou), followed by American elk (Cervus elaphus), wolves (Canis sp.), black bear (Ursus americanus), beaver (Castor canadensis), and muskrat (Ondatra zibethicus). Giant beaver, which probably did not inhabit the region for a very long period of time, were imposing aquatic mammals. An immature specimen from Indiana was over 2 m long. Adults are thought to have reached 3 m in length and weighed 215 kg; by comparison, the present day adult beaver averages about 25 kg (Dorr and Eschmann 1970). Their food source was probably herbaceous wetland plants, a diet similar to that of muskrats, since their teeth were not adapted for gnawing. Woodland caribou were last reported from Drummond Island in the St. Marys River around 1900 (Bayliss and Bayliss 1955).

Proglacial lakes and their connecting channels and outlets had an important influence on the biogeography of Great Lakes fish communities (Bailey and Smith 1981). Early proglacial lakes emptied to the Mississippi and Ohio River drainages (Figure 7B). Connections with the Atlantic, through drainage to the Susquehanna and Hudson Rivers, and with the Arctic, through drainage to Lake Agassiz to the northwest, where later established (Figure 7C). This pattern of lake formation and drainage allowed fish which had sought refuge from glacial ice in more southerly or westerly drainage basins to reinvade the Great Lakes Basin.

The earliest information on radiocarbon ages of the fish fauna from Michigan dates

************ musk-ox

********************* mammoth

****************************** mastodon

** caribou

** peccary

** spruce dominant

*********** spruce-fir dominant

** spruce-pine equal

** jackpine dominant

** pine maximum

** hardwoods increasing

** hardwood maximum

** oak-pine (rapid climatic deterioration)

14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

Time (years x 1,000 before present)

Figure 10. Time distribution in Michigan of some late Pleistocene and post-Pleistocene vertebrates, and dominant tree types (Dorr and Eschman 1970).

to only several hundred years before European settlement (Dorr and Eschman 1970). At this time, common fishes of the present Upper Great Lakes, such as whitefish (*Coregonus* sp.), muskellunge (*Esox masquinongy*), silver redhorse (*Moxostoma anisurum*), and white sucker (*Catostomus commersoni*), had already colonized the region.

CULTURAL ASPECTS

Pre-European Settlement

There is evidence of human occupation of the St. Marys River Valley for the past 11,000 years (Conway 1977). Early human occupation was probably temporary, however, since people of the Early and Middle Archaic periods (12,000-5,000 YBP) were primarily hunters who would not have been attracted to the Great Lakes shores for extended periods of time (Cleland 1982). Archaeological artifacts indicate that during the Late Archaic period (5,000-3,000 YBP), Upper Great Lakes people began to exploit spring spawning fish as a source of food immediately after winter when other resources were not abundant (Cleland 1982). From this time through the Early Woodland period, about 2,300 YBP, the technology for capturing fish evolved from harpoons, spears, and gorges to net seines.

The introduction of nets to the Upper Great Lakes and subsequent improvements in net design, such as the development of

gill nets, enabled native people to more efficiently capture fish. Early fishing remained centered around spawning seasons in spring and fall when fish which had been dispersed over wide areas of the Great Lakes concentrated in tributaries, embayments, or marshes. Here they could more easily be harvested. Net fishing, in contrast to earlier methods, required cooperation among community members. The need for cooperation, in combination with the seasonal nature of fishing, served to alter habitation patterns among Upper Great Lakes people and permanant villages began to be established. Conway (1980) distinguished between two types of communities which existed in the St. Marys River area: small, repeatedly occupied sites apparently used as summer fishing stations and much larger, more intensively occupied villages such as the village on Whitefish Island located in the St. Marys River rapids.

Whitefish Island served as a year round fishing community for Ojibwas and other Upper Great Lakes people for at least 2,000 years (Conway 1977). Archaeological examination of Whitefish Island (Table 5) suggests that intensive seasonal occupation of the area dates to around 300 B.C. (Conway 1977). As late as 1641 French missionaries Charles Raymbault and Isaac Jogues reported several thousand "Saulteurs" or people of the rapids at this village during October. At about the same time, Pere Galinu wrote in his Narratives of 1670 that the "fishery could easily support 10,000 men" (MacDonald 1977). Whitefish spawning in the fall and

Table 5. Summary of faunal remains recovered from Whitefish Island, Ontario, in the St. Marys River (Conway 1977; Hunter and Associates 1979).

Species	Species
MAMMALS	FISH
Varying hare (*Lepus americanus*)	Lake sturgeon (*Acipenser fulvescens*)
Beaver (*Castor canadensis*)	Bowfin (*Amia calva*)
Muskrat (*Ondatra zibethica*)	c.f. Brook trout (*Salvelinus fontinalis*)
Dog (*Canis familiaris*)	c.f. Lake trout (*Salvelinus namaycush*)
Black bear (*Ursus americanus*)	c.f. Whitefish (*Coregonus clupeaformis*)
Mink (*Mustela vison*)	Cisco (*Coregonus artedii*) or round whitefish (*Prosopium cylindraceum*)
Marten (*Martes americana*)	c.f. Northern pike (*Esox lucius*)
Fisher (*Martes pennanti*)	c.f. Muskellunge (*Esox masquinongy*)
Otter (*Lutra canadensis*)	c.f. White sucker (*Catostomus commersoni*)
Lynx (*Lynx canadensis*)	c.f. Longnose sucker (*Catostomus catostomus*)
c.f. Bobcat (*Lynx rufus*)	Brown bullhead (*Ictalurus nebulosus*)
Caribou (*Rangifer tarandus*)	Channel catfish (*Ictalurus punctatus*)
Cow (*Bos taurus*)	Smallmouth bass (*Micropterus dolomieui*)
Sheep (*Ovis aries*)	c.f. Largemouth bass (*Micropterus salmoides*)
c.f. Goat (*Capra hireus*)	Walleye (*Stizostedion vitreum*)
BIRDS	c.f. Sauger (*Stizostedion canadense*)
Common loon (*Gavia immer*)	Drum (*Aplodinotus grunniens*)
Bald eagle (*Haliaeetus leucocephalus*)	
c.f. Golden eagle (*Aquila chrysaetos*)	
Ruffed grouse and/or ptarmigan	
Ducks	
Shorebirds	
REPTILES	
Painted turtle (*Chrysemys picta*)	

the presence of whitefish in nearby shallow water areas in spring attracted large numbers of people to the area during these seasons. The rapids fishery for whitefish, unlike most other fishing methods of the time, was a dip net fishery. Whitefish were netted by two men in a canoe: one man paddled and guided the canoe through the rapids and the other captured fish using a long handled net (Figure 11). Accounts of the fishery by early French explorers indicated that a skillful team in a single canoe could harvest several hundred whitefish per hour, with individual fish averaging 4-6 kg each (Bayliss and Bayliss 1955).

The large concentration of people attracted to the area by fish apparently depleted the region's wildlife, making them even more dependent on the fishery for subsistence. In the St. Marys River Valley, Ojibwas lived almost entirely on fish, even making their moccasins and snowshoe laces from sturgeon skin (Bayliss and Bayliss 1955). The Ojibwa word for whitefish was Atikameg, which, literally translated, means "caribou of the waters," underscoring the importance they placed on this fish (MacDonald 1977). Cleland (1982) reported examining 37,000 bones from seven separate occupations of a village on Bois Blanc Island in the Straits of Mackinac similar to the village on Whitefish Island. In this village fish bones comprised 91%, on average, of the bones sampled in six of the occupations and 78% in the 7th. He calculated that fish supplied 66% of the usable meat obtained by these people, with whitefish and sturgeon being important species.

European Settlement

Exploration of the interior of North America was, in part, motivated by a desire to find a water route around or through the continent. Much of the early exploration of the Great Lakes area can be

Figure 11. Historical photograph of dip-net fishing at the rapids at St. Marys Rapids, ca. 1900 (courtesy of the Materna Studio, Sault Ste. Marie, Michigan).

attributed to Father Samuel de Champlain. In 1603, he ascended the St. Lawrence River to the site of present-day Montreal, where he learned of a waterway extending as far as Lake Huron and heard reports of copper deposits located beyond this lake (Bayliss and Bayliss 1955). From 1603 until his death in 1635, Champlain pursued a water route to the Orient through North America, mainly assisted by priests that he invited from France to explore the Great Lakes area and serve as missionaries. Two of these priests, Fathers Brule and Grenoble, are believed to have been the first Europeans to visit Lake Superior in 1622 (MacDonald 1977). Since the St. Marys River is the only outflow from Lake Superior, the two probably ascended the river and passed through the village at the rapids during this trip. Later missionaries to visit the area included Fathers Charles Raymbault and Isaac Jogues, who in 1641 gave the St. Marys River its present name and were thus responsible for the names given the twin cities of Sault Saint Marie, Michigan and Ontario (Bayliss and Bayliss 1955). The word sault is the current spelling of the 17th century French word saut, which in modern English means "waterfall" or "rapids." Before European settlement the area was called <u>Bawating</u> or "place of the rapids" by the Ojibwa (MacDonald 1977).

Following the visit of Raymbault and Jogues, the sault and St. Marys River soon became the center of French activity in the Upper Great Lakes and remained so for almost 50 years. Trade, fine maple-sugaring in the area, and a superb whitefish fishery at the rapids all encouraged settlement. In 1668 Father Jacques Marquette founded the first mission in the Michigan Territory at Sault Ste. Marie. Several years later, in 1671, it was the site where a special envoy of King Louis XIV claimed, in the presence of the assembled Indian Nations, the possession of the Great Lakes for France (Larson 1981). However, by 1690 La Salle's discovery of the mouth of the Mississippi River, local wars between the Chippewa and Sioux, and hostility between the French and British in the Upper Great Lakes region all acted to displace trading activities southward, and the Sault Ste. Marie area began a period of prolonged decline (Bayliss and Bayliss 1955).

Early in the 18th century England extended its influence into French territory when the French conceded Nova Scotia and Newfoundland as part of the Peace of Utrecht which ended the War of Spanish Succession (Larson 1981). By 1760 English rule extended from the maritime provinces through the Lake Superior region. Britain was interested in the Upper Great Lakes because of the profitable fur trade and its Hudson Bay Company. The potential for fur trading during this period is illustrated by the account of one fur buyer who was able to purchase 12,000 beaver skins over a 2-day period in the Sault Ste. Marie area (Bayliss and Bayliss 1955).

The establishment of the St. Marys River as an International Boundary between Canada and the United States in 1783 marked the beginning of American influence in Sault Ste. Marie. Provisions for actual boundary lines were not made, however, until the Treaty of Ghent ended the War of 1812 in 1814. American rule was established on the south side of the river in 1820 and soon after, in 1822, a garrison was built to protect American interests.

Forestry and Land Use

American rule south of the river came at a time of economic, environmental, and demographic change in the area. Depletion of beaver populations in the region caused a shift in the focus of commerce from fur trading to Lake Superior's fisheries, surrounding forest lands, and ore deposits (MacDonald 1977). During the mid-1800's, the population increased and changed in composition as people of European ancestry settled the area. In 1850 about 900 non-Indian people lived in Chippewa County, Michigan. By 1930 the county's population was almost 25,000 and a similar number of people lived in the Sault Ste. Marie district of Ontario (Veatch et al. 1927; Ont. Min. Nat. Resour. 1980). While the population of Chippewa County and Sault Ste. Marie, Michigan, has not increased substantially since the early 1900's, the population of Sault Ste. Marie, Ontario, has continued to grow. At present, the combined population of the two cities is about 100,000, with 85,000 living in Ontario. Growth of Sault Ste. Marie,

Ontario, is projected to continue and reach 120,000 by 2001 (Ont. Min. Nat. Resour. 1980).

Many of the earliest settlers were drawn to the St. Marys River Valley by the logging industry. The first sawmill in the valley was built in Sault Ste. Marie, Ontario, in 1783 (Ont. Min. Nat. Resour. 1980); it supplied wood only for local use. The commercial logging industry began in the eastern Upper Peninsula of Michigan around 1838 and developed into a booming industry by the 1870's with large rafts of logs being towed down the St. Marys River (Ont. Min. Nat. Resour. 1980; Karamanski 1984). Until 1900, white pine was the primary wood timbered because of its abundance and its low density, which allowed it to float more easily than many other species. In 1896, during the height of this period, a single sawmill at Bay Mills near the head of the St. Marys River cut 31 million board feet of white pine (Karamanski 1984).

By the turn of the century, the vast white pine forests of the region had been virtually depleted and the logging industry shifted its emphasis to hardwood species. This concentration on hardwoods continued until the 1930's when the lack of markets for wood during the depression caused timber production to decline dramatically. Following the depression, the logging industry began to recover and it continues to be an important local industry presently. Hardwoods are still logged, but pulpwoods such as spruce, balsam fir, tamarack, aspen, and jack pine make up much of the wood being cut, particularly in the eastern Upper Peninsula of Michigan.

Agricultural development of the St. Marys River Valley followed the boom in lumbering during the latter half of the 19th century. Early logging depended heavily on horses and farmers could sell hay as well as grain, beef, and pork to logging camps (Ont. Min. Nat. Resour. 1980). Agricultural production of the valley is, however, limited by an average growing season of only 134 days and shallow, poorly drained soils (Veatch et al. 1927; NOAA 1983). Present agriculture of the valley is oriented toward dairying and beef production, with hay being the chief crop. Roughly 140,000 ha of the valley is under cultivation in Michigan and Ontario combined (Veatch et al. 1927; Ont. Min. Nat. Resour. 1980).

Commercial Shipping and Industry

During the early 1800's, when American rule was being established on the south side of the river, Sault Ste. Marie became the major gateway to the northwest and to the resources of the Lake Superior region. To improve trade routes to and from Lake Superior, construction of a ship canal around the St. Marys Rapids was proposed by the Governor of Michigan in 1837 (Larson 1981). An earlier canoe canal on the Canadian side of the rapids had been destroyed during the War of 1812. However, poor planning, financial problems, and disagreement between the Federal government and the State of Michigan over property rights doomed the project before construction was actually started (Bayliss and Bayliss 1955).

Until 1855 the sole method whereby vessels could gain access to Lake Superior was a portage route on the Canadian side of the rapids. The first steamship to enter Lake Superior in 1845 was hauled over this portage on greased ways and capstans (Larson 1981). Although the process took several months, occasional vessels continued to be portaged in this way because of the increasing commerce on Lake Superior. A small fleet was established above the rapids by the early 1850's.

On August 26, 1852, the construction of a St. Marys Falls Canal was approved through an Act of the U.S. Congress (Bayliss and Bayliss 1955). The Act specified that the canal was to be at least 60 ft wide, 12 ft deep, and 250 ft long. The canal was completed in June of 1855, 22 months after construction was started and within $200 of the $1,000,000 estimated cost. It was the first in a succession of alterations to the rapids and river associated with commercial navigation.

The St. Marys Rapids have been extensively altered since those initial efforts to construct navigation canals and locks (Figure 12). Many of these alterations

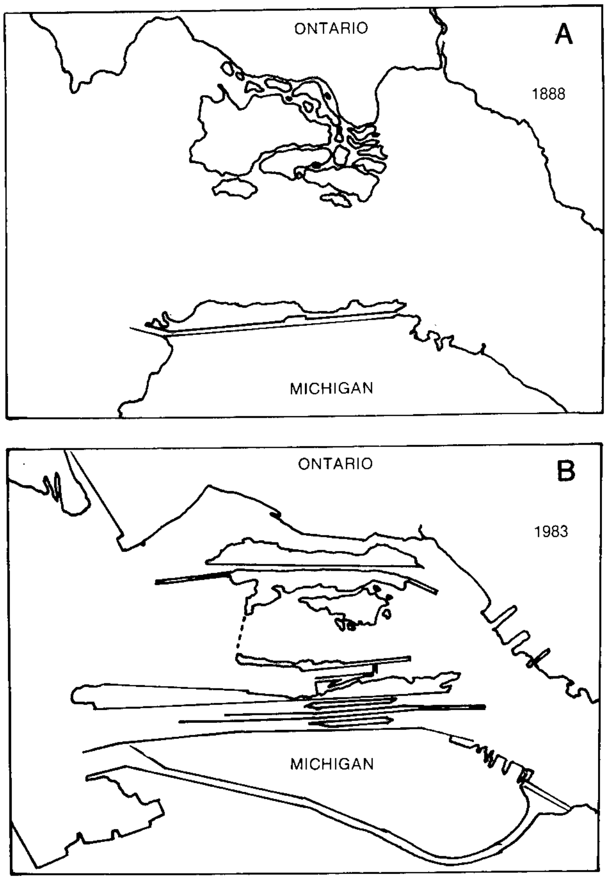


Figure 12. The rapids area of the St. Marys River: (A) 1860-88, (b) 1983 (Koshinsky and Edwards 1983).

increased trade, and stimulated greater shipping activity and the use of larger vessels (Table 6). Presently, navigation locks occupy both sides of the river: on the U.S. side, two canals feed ships into four navigation locks, while on the Canadian side, there is a single canal and navigation lock. The largest of the navigation locks is now the new Poe Lock on the U.S. side of the rapids. This lock is 365.8 m long, 33.5 m wide, and 9.8 m deep. A larger lock 394.4 m long, 35.1 m wide, and 9.8 m deep is planned and would enable even larger vessels to navigate through the river system.

Other alterations to the St. Marys Rapids include those for hydropower development, rail and highway traffic, and flow control structures (Table 6). Use of the rapids for hydropower began in 1898 with construction of the Edison Sault Electric Company's power house and canal. Later, a second hydroelectric plant on the Canadian side of the rapids and a third plant operated by the U.S. Army Corps of Engineers were constructed. At present, an average 93.3% of the river's flow at the rapids is diverted through hydroelectric power plants (Table 7). The intense demand for water created by hydropower and shipping interests led to the construction in 1921 of flow control structures. Called compensating works, the flow control structures are a series of 16 gates which span the head of the remaining rapids. These gates may be opened to allow flow over the rapids or closed to divert water away from the rapids and through power or shipping canals, thereby compensating for variations in natural discharge caused by changing water levels of Lake Superior.

During the past 15 years, increased demand for water has heightened concerns for maintaining water flow sufficient to support aquatic biota inhabiting the rapids. After analyzing the hydrologic characteristics of the rapids and flow requirements of the organisms inhabiting them, Koshinsky and Edwards (1983) recommended that flow either be maintained at roughly 565 m^3/s or adequate water levels be maintained by strategic placement of berms. A series of berms was constructed in 1986 to maintain water levels over the rapids.

In addition to modifying the rapids, commercial shipping necessitated the dredging of natural channels in shallower portions of the river. As the sizes of navigation locks were increased to accommodate ever-larger vessels, the sizes of ship channels had to be increased to fully utilize these locks. In 1857, soon after the first lock was completed, a 37-m wide, 3.7-m deep channel was dredged through shallow portions of lower Lake George and the East Neebish Rapids (Table 6). This route through Lake George was later abandoned in favor of a route through Lake Nicolet because of the difficulty in navigating the East Neebish Rapids (Larson 1981). When completed in 1894, the channel through Lake Nicolet was 92.3 m wide, 6.1 m deep, and extended from the upper lake through the Middle Neebish Channel

Table 6. Chronology of engineering events associated with the development of the St. Marys Rapids and River. Adapted from Koshinsky and Edwards (1983).

Year	Event
1797	Navigation lock 11.5 m long constructed on Canadian side.
1822	Raceway and sawmill built on American side by U.S. Army.
1839	Navigation canal started on American side, construction later aborted.
1855	Navigation lock completed on American side; construction had been started in 1853.
1859	Dredging of Lake George Channel completed.
1887	Lock of 1855 dismantled and replaced by larger set.
1881	Weitzel Lock on American side completed.
1888	International railway bridge completed.
1894	Dredging of Lake Nicolet Channel completed.
1896	Canadian Government canal and lock completed; old State locks on American side replaced by Poe Lock.
1901	Construction of compensating works begun.
1902	Edison Hydroelectric Canal and power plant completed; canal diverted enough water to operate 41 turbines, each using approximately 10.6 m^3/s.
1908	Ship canal through West Neebish Rapids (rock cut) completed.
1914	Davis Lock on American side completed.
1915	Additional 37 turbines added to Edison Hydroelectric plant.
1916	Hydroelectric canal and plant completed on Canadian side.
1919	Sabin Lock on American side completed.
1921	Construction of compensating works completed.
1927	Widening of Middle Neebish Channel completed.
1933	Widening of canal through West Neebish Rapids completed.
1943	MacArthur Lock on American side completed, replacing Weitzel Lock.
1969	Abitibi Paper Company water use reduced from approximately 198 to 1 m^3/s permanantly.
1982	Hydroelectric plant on Canadian side redeveloped and capacity increased from 510 to 1,076 m^3/s.
1986	Berm constructed to maintain water level over rapids.

Table 7. Average discharge of the St. Marys River over the rapids, through hydroelectric power plants, and through navigation locks (Koshinsky and Edwards 1983).

Area	Discharge (m^3/s)	Discharge Percent
Rapids (compensating works)	99.2	4.7
U.S. navigation locks	36.8	1.7
Canadian navigation locks	5.7	0.3
U.S. Government power plant	359.5	16.9
Edison Sault Electric Company	631.3	29.7
Great Lakes Power Corporation	990.0	46.7
Total	2,122.5	100.0

between Sugar, Neebish, and St. Joseph Islands into Munuscong Bay. Subsequently, the West Neebish Channel below Lake Nicolet was opened to shipping by excavating the West Neebish Rapids, an area now known as "the rock cut" because the ship channel was literally cut through bedrock. In the 1920's all channels were deepened to 7.4 m and later deepened to 8.3 m. At present, 101 km of shipping channels, ranging from 91 to 457 m in width, extend from above the rapids south through Munuscong Bay (Larson 1981).

Traditionally, the shipping season extended from ice break-up in mid-April through mid-December when ice formation impeded ship traffic and operation of the locks. During the 60's, however, demand for commodities being shipped on the Great Lakes increased and the shipping season was extended past mid-December to early January despite problems caused by ice. Later, the River and Harbor Act of 1970 and the Water Resources Development Act of 1974 authorized a Winter Navigation Demonstration Program for the St. Lawrence Seaway. The goal of this program was to determine the feasibility of extending the navigation season on the Great Lakes. From 1974 through the winter of 1978-79 the locks at Sault St. Marie remained open all year and shipping was conducted during winter months. Since 1979 the locks have been closed for the season between late-December and mid-January while opening dates have varied between 23 March and 1 April (Liston et al. 1986). The program successfully demonstrated that engineering changes in the operation of locks, vessels, and the river itself could extend navigation beyond traditional winter closing dates. However, recent declines in the demand for iron ore and other commodities have resulted in only modest support for this program.

The St. Marys River is utilized as a source of water in manufacturing as well as for shipping and hydropower. The dominant manufacturing industry of the area is the Algoma Steel Corporation's steel mill at Sault Ste. Marie, Ontario (Acres Consulting Service, Ltd. 1977). This mill employed 10,000 people in the mid-1970's, but employment levels have declined since then. The second largest industry, Abitibi Paper and Pulp Corporation, is also located in Sault Ste. Marie, Ontario, and employs 450 people. No other major industries are located along either side of the river. In the past, minor amounts of copper, lead, and silver were mined in the St. Marys River Valley and dolomite was quarried on East Neebish Island. A quarry on Drummond Island was once the world's largest producer of dolomite, but production has been greatly reduced in recent years. Other than dredging of minor amounts of gravel from the upper river, mining appears to have had little direct influence on water quality in the river.

Water quality throughout most of the river is good, the exception being the area downstream from Sault Ste. Marie along the Ontario shoreline. Here industrial discharges from Algoma Steel and Abitibi Paper have decreased water quality (Veal 1968). The main contaminants discharged from these industries are phenols, cyanide, ammonia, and heavy metals (Acres Consulting Service Ltd. 1977; Ont. Min. Environ. 1983). Sediments of the upper river have also been contaminated with wood chips, nitrogen, and oil and grease originating from Algoma Steel and Abitibi Paper (Veal 1968; Hiltunen and Schlosser 1983). Sediments in the vicinity of a former leather tannery immediately upstream from the rapids on the Michigan side of the river are also contaminated with chromium, cyanide, copper, and lead (Kenaga 1979).

COMPARISONS WITH OTHER CONNECTING CHANNELS

This monograph is published in the estuarine profile series, although the St. Marys River would not be considered an estuary by most definitions or classification schemes (Cowardin et al. 1979). The term estuary is most often applied to transitional environments between marine and freshwater where salinity gradients occur. However, freshwater estuaries are also recognized. For the Great Lakes, an estuary is defined as "the lower reach of a tributary to the lake that has a drowned river mouth, shows a zone of transition from stream water to lake water, and is influenced by changes in lake level as a

result of seiches or wind tides" (Bates and Jackson 1980). Brant and Herdendorf (1972) were among the first investigators to describe the characteristics of Great Lakes estuaries, pointing out their physical and chemical similarities to marine estuaries. The above definition encompasses characteristics of the St. Marys River, but for comparative purposes we have chosen to refer to the river as either a river system or a Great Lakes connecting channel.

River systems have classically been viewed as progressions from rocky high-gradient headwater streams to low-gradient mud-bottomed rivers, with channels progressing from straight, to braided, to meandering patterns (Minshall et al. 1985). The St. Marys River, with its large volume of oligotrophic water entering at the headwaters and relatively little flow contributed by tributaries, does not fit this classic view and may well be unique among North American rivers. The discharge of Lake Superior into the river influences the ecosystem in ways analogous to the ways large hydroelectric reservoirs influence rivers, shifting stream ecosystem structure and function in either an upstream or downstream direction, depending on the location of the outflow relative to the reservoir thermocline (Ward and Stanford 1983). However, natural meteorological cycles and wind conditions acting on Lake Superior make discharge conditions less stable than those from hydroelectric dams, and it is unlikely that the influence of discharge on ecosystem function or structure would be unidirectional. The upper reach of the Angara River, flowing from the ultra-oligotrophic Lake Baikal in the Soviet Union, may be similar to the St. Marys, but comparative data are lacking.

The rivers most similar to the St. Marys are other connecting channels of the Great Lakes: the St. Clair, Detroit, Niagara, and St. Lawrence Rivers. Like the St. Marys, these rivers receive water from one Laurentian Great Lake and, excepting the St. Lawrence River, discharge into another. The St. Lawrence River empties into the Gulf of St. Lawrence below Ste. Foy, Quebec. While all the connecting channels share certain physical characteristics, drainage patterns from the Great Lakes and human settlement have contributed disproportionally to the degradation of connecting channel ecosystems in the lower Great Lakes. Drainage from the Great Lakes, except for a minor diversion from Lake Michigan at Chicago, is from Lake Superior through Lakes Huron and Michigan, Erie, and Ontario before finally discharging into the St. Lawrence River. Because drainage is from one lake to another, the size of the drainage basin influencing the lakes and their connecting channels becomes progressively larger as one moves down and out through the Great Lakes ecosystem (Table 8).

While the size of the drainage basin has some influence on ecosystem character, the major influence on lower Great Lakes connecting channels has been patterns of human population settlement. Population growth in the Great Lakes Basin has centered in the south, while the northern

Table 8. Summary of physical characteristics of Great Lakes connecting channels (Upchurch 1976).

Channel	Length (km)	Drop (m)	Average flow (m^3/s)	Total land drained (km^2)
St. Marys River	112	6.8	2,100	128,000
St. Clair River	43	1.5	5,300	379,700
Detroit River	51	1.0	5,400	397,600
Niagara River	60	99.3	5,700	456,400
St. Lawrence River	808	74.0	6,700	527,100

portions of the basin remain relatively undeveloped. Furthermore, access to water for human consumption, transportation, and industry has tended to concentrate the greater population of the south near Great Lakes connecting channels or tributary mouths. The metropolitan areas of Detroit, Buffalo-Niagara Falls, and Montreal all are situated along the lower connecting channels. Heavy use of these waterways for industry, shipping, electrical power generation, and wastewater treatment has resulted in the degradation of water quality, including the contamination of both water and sediments with toxic chemicals.

These water quality problems, in turn, have contributed to shifts in the composition of biological communities. Today blue-green algae predominate over diatoms or green algae, and oligochaetes make up >90% of the benthic fauna in some reaches of the Detroit River (Hiltunen and Manny 1982; Manny et al., unpubl. MS.). Fishes such as yellow perch (Perca flavescens) and rock bass (Ambloplites rupestrus) have become abundant in the lower connecting channels, while historically important species such as whitefish have been eliminated (Edsall et al., unpubl. MS.).

While the St. Marys River has suffered some degradation in water quality and has been physically altered by humans, it retains more of the biological components common to the early Great Lakes than do any of the other connecting channels. As will be pointed out in later chapters, relatively little is known about the influence of human activities on the ecology of the St. Marys River. In lieu of either quantitative or qualitative information on certain biological components, published information from other Great Lakes connecting channels may shed light on mechanisms contributing to changes in population abundance and community patterns over time.

CHAPTER 2. THE ENVIRONMENT

TEMPERATURE, WIND, AND LIGHT

Air Temperature

Air temperatures for the St. Marys River region are derived from the weather data collected at the National Weather Service Office at Sault Ste. Marie, Michigan (NOAA 1984). Extension of these temperatures to the entire length of the river is justified based on the findings of Greene (1983). He reports that from November 1971 to April 1977 mean monthly air temperatures for Sault Ste. Marie, the Dunbar Forest Experiment Station (some 22 km south), and De Tour Village, Michigan, at the mouth of the river were highly correlated and that the station means for Sault Ste. Marie and Dunbar were not significantly different. Station means for De Tour Village were significantly warmer than Sault Ste. Marie but only by 1 to 2 °C.

At Sault Ste. Marie, the coldest month of the year is January, which averages -10.4 °C, while July is the warmest month, averaging 17.5 °C (Figure 13). Air temperatures in this area are moderated throughout most of the year by Lake Superior, which seldom freezes over. Based on the 30-year period 1951-80, the average first day of 0 °C in the fall is September 27 and the average last occurrence in the spring is May 26. Most summers pass without temperatures reaching 32.2 °C and the highest temperature on record is 36.7 °C, which occurred in 1888.

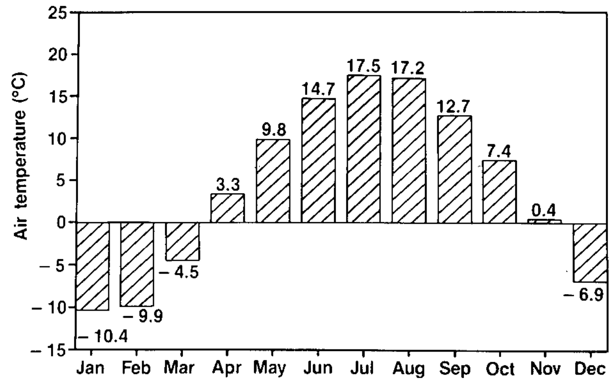


Figure 13. Mean monthly air temperature for Sault Ste. Marie, Michigan. The means are computed for a 30-year period, 1951-80 (NOAA 1984).

Water Temperature

The water temperatures of the St. Marys River are typically cold and are near 0 °C for 4 months of the year. Temperatures of the headwaters are primarily dictated by the surface temperatures of Whitefish Bay, which range from 0 to 16 °C (Phillips 1978). These waters are warmer than the main body of Lake Superior; at the time of maximum water temperature in mid-September this difference can be as great as 4 °C. The typical annual cycle for Whitefish Bay begins with water temperatures near freezing for the months of January, February, and March, reaching a minimum sometime during March. By late April the waters begin to warm, reaching a maximum of 16 °C by mid-September, after which the water cools roughly 12 to 16 °C between October and January. A similar cooling cycle has been reported for waters of the power canal at Sault Ste. Marie, Michigan. For those waters, the mean date at which the water cools to and remains at 0 °C is January 2, although the date ranges from December 6 to January 20 (Greene 1983).

Ice forms on the river differentially, with broad, shallow areas usually freezing first and faster, and deeper reaches freezing later. Greene (1983) reported that Munuscong Lake was the first site to

freeze over during his study, with a mean date of December 17. Raber Bay froze over by December 21, followed by Izaak Walton Bay on January 2. The last sites to freeze over, all in mid-January, were the faster reaches of the river at Six Mile Point, Upper Lake Nicolet, and finally Frechette Point. Maximum ice thickness also occurs differentially at different sites of the river but not necessarily in the same order as above. In fact, Greene (1983) reported that maximum ice thickness occurred at Frechette Point on February 25 while Munuscong Lake did not reach maximum ice thickness until March 16. The pattern of ice break-up and ice-free conditions is the reverse of the freeze-up trends: faster, deeper areas break up sooner than the slower, shallower areas. These patterns of ice growth and decay can vary significantly from year to year (Greene 1983).

Waters within emergent wetlands warm more rapidly in spring and reach greater maximum summer temperatures than water offshore. During 1983, continuous water temperature records were provided by recording thermistors positioned 25 cm above the sediment surface 600 m offshore from the wetland face (the face being the boundary between open-water and emergent plants), 60 m shoreward, and 240 m shoreward of the west Nicolet Lake wetland face (Figure 14; Liston et al. 1986). Daily water temperature records from the Sault Edison power canal at Sault Ste. Marie were also available for comparison with Lake Nicolet reach data. Water temperatures recorded at the power canal were similar to mean daily water temperatures at the offshore site in Lake Nicolet. Differences were generally <1.0 °C, indicating little spatial variability. This was not the case when offshore channel water temperatures were compared to temperatures of water masses at two locations within the wetland (Figure 15). Ice went off the wetland during the first week in April 1983, while ice-off on the adjacent navigation channel began in March. Water temperature closest to the shore rose rapidly near the time of ice-off and quickly exceeded offshore channel temperatures (Figure 15). There was approximately a 1-week lag in temperature increase for the wetland area closer to the channel. Once the wetland sediments

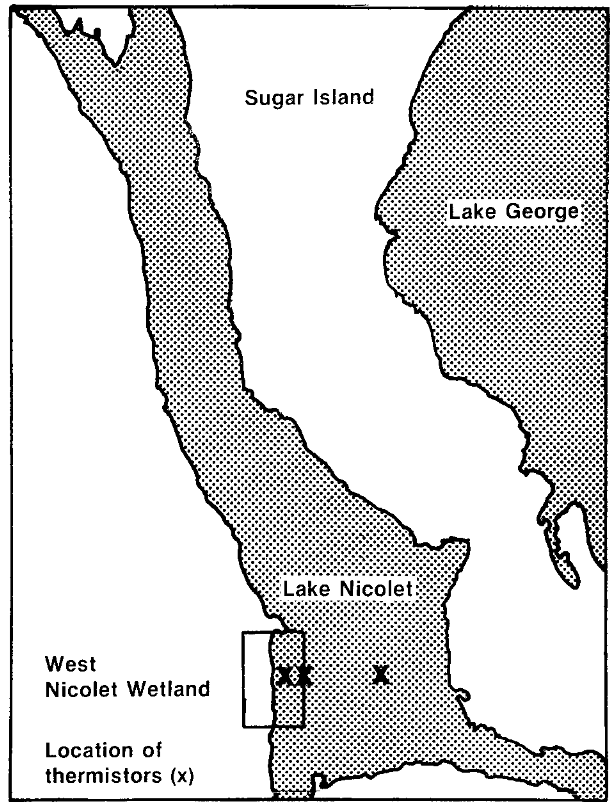


Figure 14. Location of the emergent wetland near the Dunbar Forest Experiment Station.

in this area thawed, temperatures rose abruptly and exceeded offshore channel temperatures by 1 to 6 °C until late July. Both wetland sites were warmer than channel waters until August and were nearly the same at all locations for the last 3 weeks in August and the first week of September. Thereafter, wetland sites decreased in temperature more rapidly than the channel waters. The wetland site farthest from the shore reached 0 °C 4 weeks earlier than the channel, and ice sheets formed on the wetlands prior to formation in the adjacent channel.

Growth of the ice sheet was measured in the west Lake Nicolet wetland during the winter of 1982-83 (Liston et al. 1986). A thin sheet of ice was present by late December. It grew gradually thicker until it reached a maximum thickness of 60 cm in mid-February in outer portions of the wetland. Systems of cracks were observed in the ice sheet, but open cracks--typical of hinges between anchored shore-zone ice and

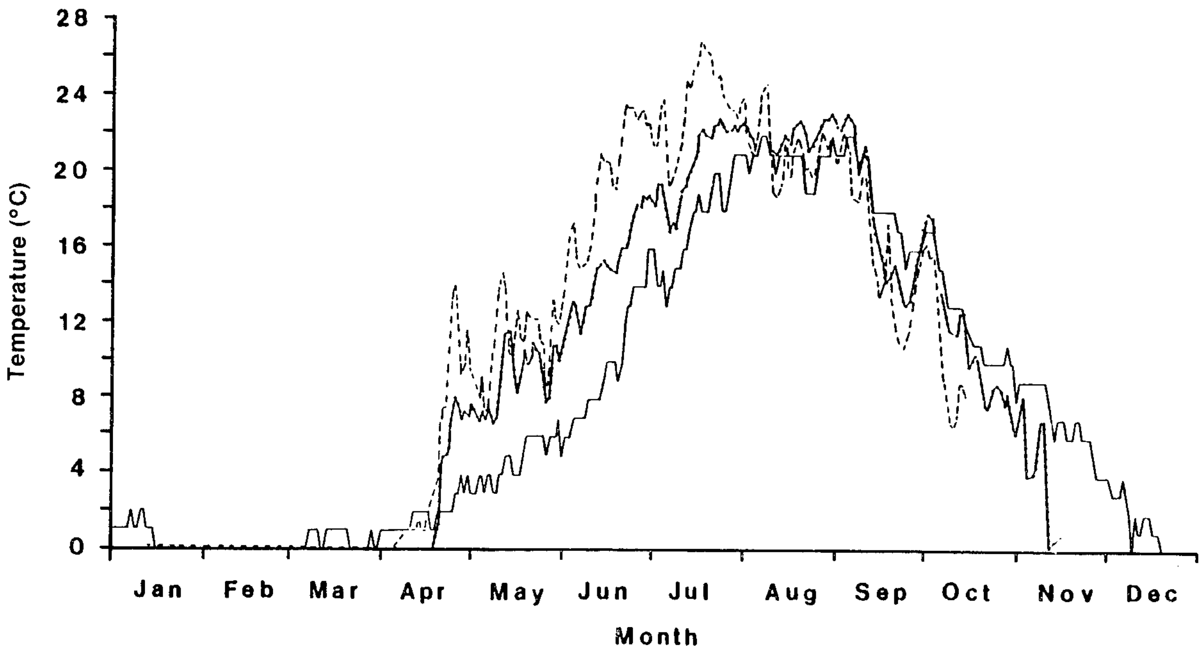


Figure 15. Mean daily water tempertures for two sites within the Dunbar emergent wetland and adjacent navigation channel in 1983.

floating ice moving with waves and currents--were never observed. Borings made along four transects of this wetland in mid-January 1983 revealed that in the nearshore areas the ice sheet was vertically continuous with the upper surface layers of the sediments, where over 90% of the emergent plant rootstocks were located. These data suggested that as winter progressed, this frozen sediment-ice junction would extend further towards the channel. If hinges did not occur in the ice sheet, vertical movement of the sheet caused by waves moving onshore from channel areas could uplift and detach plant rootstocks from sediments at the frozen sediment-ice junction. Wind driven waves are likely to cause such disruption in shallow water portions of the wetlands during early ice sheet formation when open water exists offshore in the river. Water movements associated with winter navigation would be the sole cause of disruptive uplift forces during the time of late ice sheet development and during the winter period of stable maximum ice sheet thickness, when offshore waters are frozen.

During the early phases of the spring ice-off process, thawing and opening occurred in very shallow water near the shore zone. During this phase, the ice sheet remained vertically continuous with frozen sediments in intermediate depths (ca. 0.4 m) in the wetland. Ice floes moved down offshore channels before ice on the wetland broke up. As offshore areas cleared of ice, ice floes were exported from the upstream outer fringes of the wetland. These floes tended to be imported by currents into other portions of the wetland downstream. The potential for imported floes to affect the rootstocks in sediments of wetlands appeared dependent on water depth, size and thickness of floes, and force of movement of floes. At intermediate water depths in the wetland, sediments with rootstocks tended to remain frozen as the ice sheet thinned, broke up, and cleared. During the ice-off process, movement of ice by currents and waves appeared to have potential for localized disruptions of rootstocks, particularly at intermediate water depths in the wetland.

Wind Patterns

Phillips (1978) presented wind data for Lake Superior with reference to Whitefish

Bay and Sault Ste. Marie. Whether these data are applicable to the entire length of the St. Marys River is unknown. Lake Superior lies in the mid-latitude zone of westerly winds. Northwest and southwest winds blow about 40% of the time, with wind speeds averaging between 8 and 15 m/s over the lake. Light (less than 4 m/s), persistent winds are much less frequent over the lake as compared to land stations. At Sault Ste. Marie these light surface winds are least frequent in the spring, occurring about 46% of the time, and most frequent during the summer and early fall months, when they occur about 65% of the time. These light winds are strongly affected by urban areas, landforms, lakes, and streams. Variations in diurnal wind speeds follow the usual pattern of higher velocities during mid-afternoon, with lower speeds at sunrise and toward dusk. There is also a frequent local circulation pattern of air from lake to land during the daytime and from the land to lake during the nighttime because of air and water temperature differences.

Lake Superior and, similarly, the St. Marys River are subject to important wind-driven forces such as waves and seiches. Wind speeds are generally higher over the lake due to the relative lack of friction, and are especially strong when the direction allows a long fetch over open water. Strong, prevailing northwesterly winds cause the formation of large waves which can travel long distances before reaching Whitefish Bay and the headwaters of the St. Marys River. The highest reported 1-min wind on the lake was 41 m/s in June 1950. At Sault Ste. Marie, Ontario, the fastest wind was 24 m/s in November 1963 (Phillips 1978), and at Sault Ste. Marie, Michigan, a wind speed of 27 m/s was recorded in November 1975 (NOAA 1985); both land values were significantly less than that reported for the lake. For Sault Ste. Marie, Michigan, Phillips (1978) compared wind directions during wet and dry periods for 4 months (January, April, July, and October) over a 9-year period, 1963-71. Prevailing wind direction during wet weather in January was from the northwest or west, with south winds two to three times more likely to occur during wet weather. Northwest and west winds had an almost equal chance of occurring on dry as wet days. A wet day is defined as one in which a measurable amount (0.2 mm) of precipitation occurs over most of the land basin. Winds in April had a much greater directional variability, blowing for more than half the time from the southerly quadrant. Winds with an easterly component predominated, especially southeasterlies during wet weather, and exceeded 15% frequency of occurrence. Summer winds returned to being predominantly from the westerly quadrant and there was an equal percent frequency of occurrence (35%) of both wet and dry weather winds from the west. October wind directions begin to resemble January patterns and are mostly from the westerly quadrant. Overall, the prevailing winds are from the westerly quadrant.

Regions of wide expanse (for example, Lake Nicolet and Munuscong Lake) have shorelines variously exposed to waves and currents. Shores with the most exposure have no emergent vegetation; the bottom is rock or shifting sand. Where emergent wetlands do occur, two vegetation types appear to result from the degree of exposure: (1) least-protected sites have *Scirpus americanus* or *Eleocharis smallii* as the dominant vegetation types, and (2) most-protected sites have *Scirpus acutus* and *Sparganium eurycarpum* as the dominant vegetation types.

Least-protected sites occur along the eastern or windward shore of the river and are subjected to the greatest amount of wind-generated waves. Some most-protected sites occur on the eastern shore of the river but are found in sheltered locations, such as Baie de Wasai and Shingle Bay in Lake Nicolet. The western shore of the Lower St. Marys River lies in the lee of the prevailing winds and development of most-protected emergent wetlands is more pronounced along that shoreline. The large tract of *Scirpus acutus* and *Sparganium eurycarpum* that extends from just north of the Charlotte River northward 10 to 12 km is a good example of wetland development on a most-protected site. This site is described in detail in Liston et al. (1986) and portions of it are shown in Figure 24.

Light

Light is another important environmental parameter providing physical energy to the St. Marys River. This energy not only heats the water and sediments in shallow reaches of the river but also provides the energy needed by the primary producers for photosynthesis. These organisms utilize electromagnetic radiation in the wave band from 400 to 700 nm (referred to as photosynthetically active radiation or PAR). PAR photon flux density (PFD), which is expressed as moles of photons per unit area per unit time, varies considerably on both a short- and long-term basis. Short-term fluctuations, on the order of minutes or days, are the result of variable cloud cover and atmospheric moisture, both of which reduce the amount of solar radiation impinging on the river. Long-term fluctuations, or annual cycles, are the result of the changing angle of the sun. Maximum instantaneous PAR photon flux densities measured at the surface of the waters of the St. Marys River are about 1,900 microEinsteins per meter squared per second ($\mu E \cdot m^{-2}\ sec^{-1}$) and occur near solar noon on cloudless days in summer. Typically, values are much less than this since this area is predominated by cloudy days and high levels of atmospheric moisture. Daily PAR values measured for the St. Marys River at the Dunbar Forest Experiment Station (46° 19'N, 84° 8'W) varied greatly but showed a gradual increase from minimal values in the winter to the highest values during the summer (Figure 16). In some cases, daily photon flux values exceeded the maximum full-sunlight curve. However, the maximum photon flux curve was empirically derived from relatively long-term PAR records for the site. Figure 17 illustrates the maximum full-sunlight curve on which is superimposed the growing season for emergent and submersed plants using germination temperature thresholds for start in the spring and field observations for the end in the fall (Liston et al. 1986); the period of ice and snow cover is also shown.

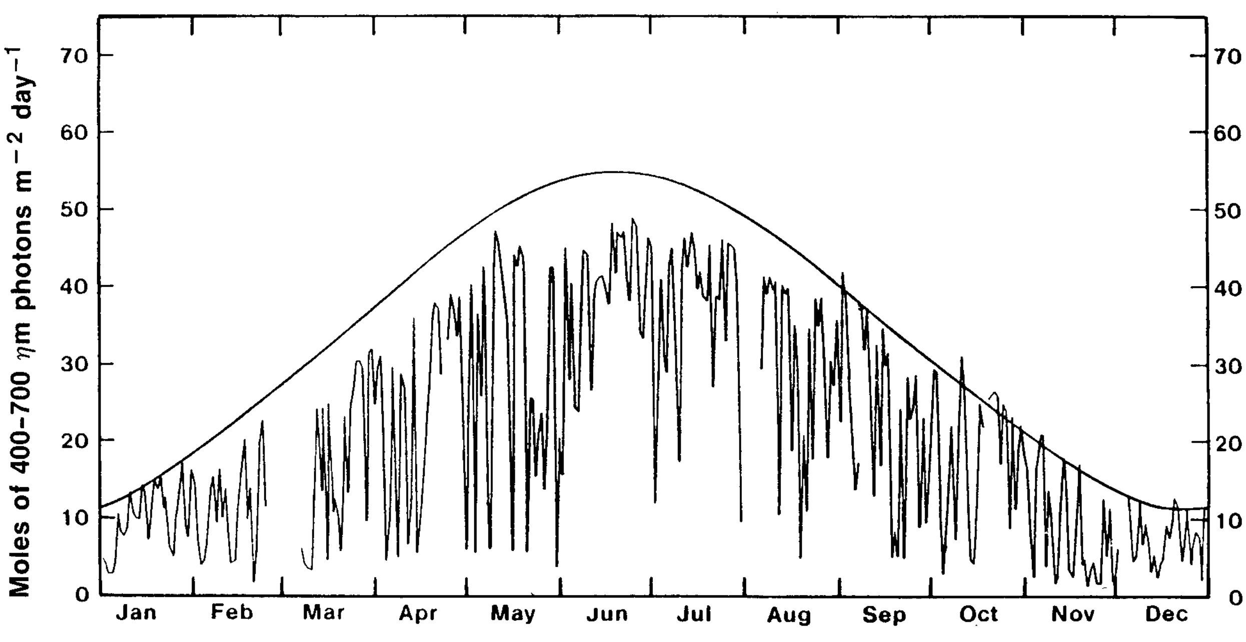


Figure 16. Annual curve of photosynthetically active radiation (PAR) 400 to 700 nm at the Dunbar Forest Experiment Station. The smooth upper line represents the calculated full-sunlight maximum curve for that location; 1982 daily values plotted below (Liston et al. 1986; McNabb, unpubl. data).

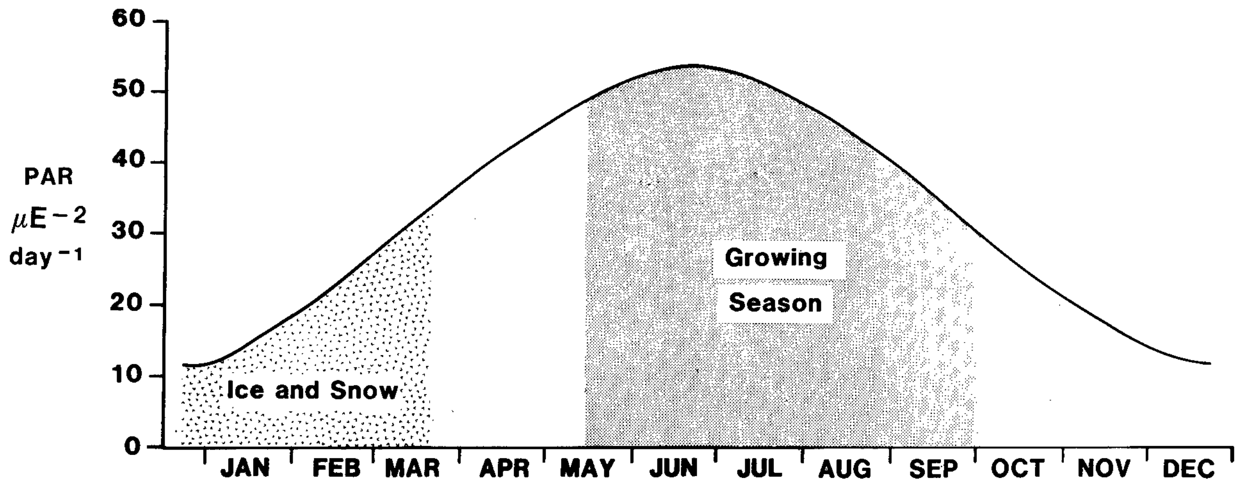


Figure 17. Calculated full-sunlight maximum curve for the Dunbar Forest Experiment Station showing ice and snow cover on the St. Marys River and the growing season for submersed and emergent aquatic plants (McNabb, unpubl. data).

PRECIPITATION AND HYDROLOGY

Precipitation

The winters in the St. Marys River area are cold and snowy with total snow-fall accumulations ranging from a minimum of 0.82 m in 1899-1900 to a high of 4.54 m during the winter of 1976-77. November 21 is the average date for the appearance of permanent snow cover which normally remains until April 7.

The following are 30-year (1951-80) averages for precipitation (as water equivalents) at Sault Ste. Marie, Michigan (NOAA 1985). The annual mean is 85.0 cm. Monthly variations are significant: February is the driest month, with a normal monthly mean of 4.3 cm, while September is wettest, with a monthly mean of 9.9 cm. Monthly averages over the 30-year record are also quite variable. The minimum monthly average was 0.4 cm for October 1963, while the maximum monthly average was 24.1 cm for August 1974. Maximum precipitation in 24 hours ranged (on a monthly basis) from a low of 2.8 cm in February 1977 to a high of 15.0 cm in August 1974. These data are in close agreement to values reported by Phillips (1978) for overall averages of precipitation on Lake Superior.

Hydrology

Water budgets for Lake Superior were developed by both the International Joint Commission (presented in Matheson and Munawar 1978) and Bennett (1978). Both are in close agreement and show that there are only two major losses of water from the lake: by outflow via the St. Marys River or by evaporation. Losses of water by municipal or industrial uses or by ground-water flow are considered to be negligible. Outflow to the St. Marys River accounts for 65% of the total losses.

Outflow from Lake Superior via the St. Marys River has been recorded since 1860 and has fluctuated greatly (Figure 18). The mean flow rate for the 124 years of record (1860-1984) is 2,144 m^3/s, while monthly rates have ranged from a minimum of 1,161 m^3/s in September 1955 to a maximum of 3,597 m^3/s in August 1943. It should be noted that since the completion of the Long Lac and Ogoki Diversions in the 1940's, in which some waters originally draining north into James Bay were diverted to Lake Superior, there has been an increase in the annual flow. The effect of these diversions has been an increase of 196 m^3/s in the mean discharge of St. Marys River. Monthly flows (mean, maximum, and minimum) of the river from 1900 to 1978 are presented in Figure 19. The flow is least in March

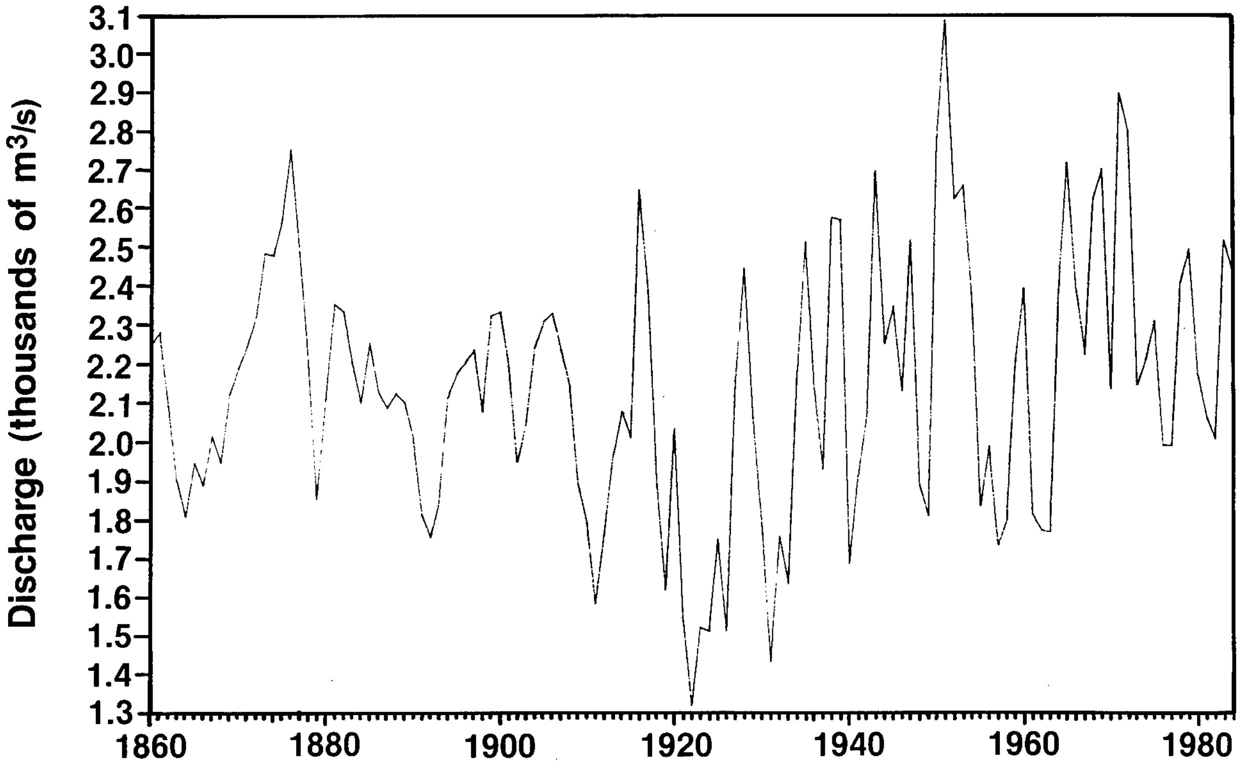


Figure 18. Yearly average discharge of the St. Marys River at Sault Ste. Marie from 1860 to 1984 (Quinn and Kelley 1983; U.S. Army Corps of Eng., Detroit District, unpubl. data).

(1,869 m^3/s), when Lake Superior levels are lowest, and greatest in September (2,379 m^3/s), when the lake level is highest.

As mentioned in Chapter 1, there are a number of watersheds that drain into the

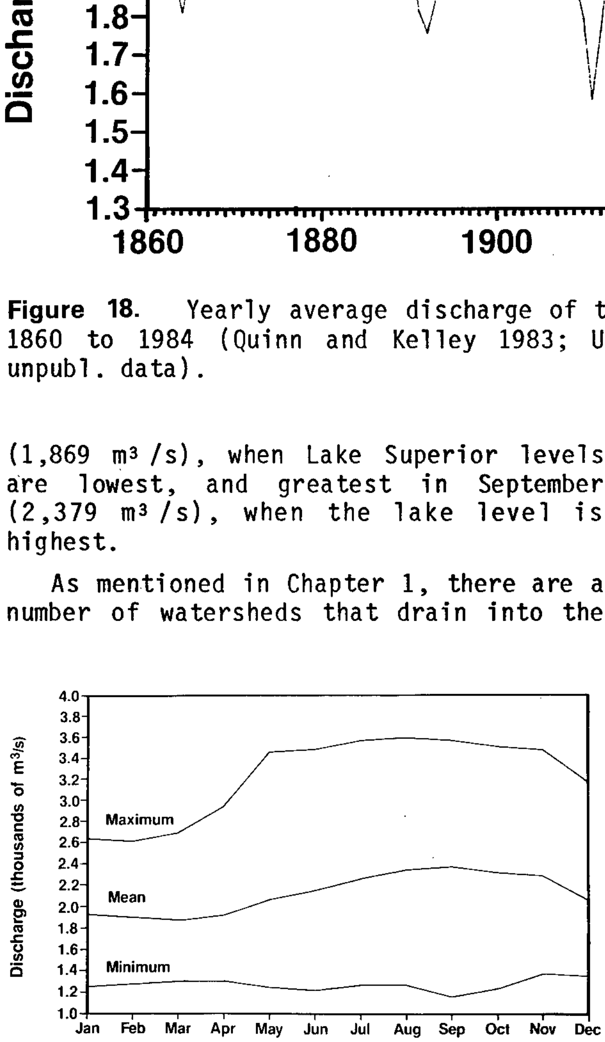


Figure 19. Monthly average discharge of the St. Marys River at Sault Ste. Marie for the period 1900 to 1978 (U.S. Army Corps of Eng., Detroit District, unpubl. data).

St. Marys River. By far the most important is the Lake Superior Basin, which also includes the Goulais River on the Canadian side. The other drainage basins that discharge to the St. Marys River are all of much smaller magnitude than that of Lake Superior (cf. Figure 2). On the U.S. side, these include basins which are drained by a number of small streams in the vicinity of Sault Ste. Marie, Michigan, north of the Charlotte River; the Charlotte River; Little Munuscong River; Munuscong River; and the Gogomain River. Together, these four rivers drain 64% of the immediate watershed. On the Canadian side, a number of watersheds are drained by the Big Carp River, Little Carp River, Root River, Garden River, Little Garden River, Echo River, and Bar River. Except for discharge measurements of Lake Superior, there is little information on flows from the other watersheds that drain into the St. Marys River. The Water Resources Branch of the Ontario Ministry of the Environment has discharge data for the

Root River dating back to 1971. On the U.S. side there have been no flow data collected on tributaries draining into the river. However, Liston et al. (1986), using data presented by Sommers (1977) for annual precipitation, runoff, and ground water, estimated annual discharge for various portions of the immediate watershed of the St. Marys River below Mission Point on the U.S. side (Table 9).

The largest drainage basin after Lake Superior is the Munuscong River which was estimated to discharge 1.9 x 10^{-6} m^3 per year. During 1982 the average discharge of the St. Marys River at Sault Ste. Marie was 1,988 m^3/s. Using these values, it can be calculated that the annual discharge of the Munuscong River was equaled by 16 min of discharge for the river at Sault Ste. Marie in 1982. Mean discharge for the total watershed was estimated to be 0.15 m^3/s (Table 9). In 1982, this discharge rate was 0.007% of the average discharge of the St. Marys River at Sault Ste. Marie. It is apparent from these calculations that Lake Superior exerts the most influence on the water budget of the St. Marys River.

Discharge measurements were made by Liston et al. (1986) on the outlet channels from Lake Nicolet during the interval April-October 1983. Total discharge from this reach of the river for this period was found to be 74% of the river's discharge at Sault Ste. Marie. Flushing rates (discharge divided by lake volume) were calculated and found to average 1.31 lake volumes per day. It is clear from these results and hydrographic features of lower reaches of the river that any materials in solution or suspension tend to be transported through the length of the St. Marys River in a short period of time (days). However, this is a generalization and comparisons between near-channel sites and sites closer to shore in the broad reaches of the river showed areas of stagnation (Liston et al. 1986).

NOAA (1985) reports that the swiftest currents in the navigable channels occur at the Little Rapids Cut, where speeds vary from 1.0 m/s at a high water discharge of 3,115 m^3/s to 0.6 m/s at a low water discharge of 1,614 m^3/s--a 36% reduction in speed for those two discharge extremes. In other reaches of the river the speed can be reduced by as much as 46% between those two levels of discharge.

Current velocities lessen away from the navigable channels (U.S. Army Corps of

Table 9. Area of portions of the immediate watershed of the St. Marys River below Mission Point and estimates of volumes of water in runoff per year and per second (from Liston et al. 1986).

Region	Area (km^2)	Runoff (m^3/yr)	Mean (m^3/s)
Islands:			
Sugar Island	44	183,860	0.01
Neebish Island	55	229,820	0.01
St. Joseph Island	146	449,300	0.01
Lime Island	4	13,000	0.01
Mainland:			
Above Charlotte River	86	358,920	0.01
Charlotte River	187	642,920	0.02
Little Munuscong River	179	576,910	0.02
Munuscong River	562	1,880,300	0.06
Gogomain River	95	254,610	0.01
Totals	1,358	4,589,640	0.14

Engineers 1984) and in some areas are virtually nil along the shoreline unless induced by winds or the passage of commercial vessels. McNabb et al. (1986) found that current speed in a channelized area of an emergent wetland along the river in the Lake Nicolet reach went from 0.0 m/s to 1.0 m/s as a commercial vessel passed the study site.

The water levels of the St. Marys River are subject to three types of fluctuations: seasonal, long range, and short period. Seasonal fluctuations cover a period of 1 year, long-range fluctuations a few or many years, and short period fluctuations from several minutes to a few days. Seasonal fluctuations are the most regular, with highest water levels occurring during the summer and the lowest occurring during the winter. These fluctuations are the result of a number of factors, including precipitation, evaporation, and runoff. These are compounded by the regulated monthly flows of the river at Sault Ste. Marie. On average there is about a 0.3 m change in water-level fluctuation during a year. Long-range fluctuations have been more dramatic, with a 1.2 m difference between the highest and lowest monthly mean levels in the Upper St. Marys River and 1.5 m in the lower river over the last 80 years (NOAA 1985). Short-period fluctuations can also be quite dramatic as indicated by one recorded event in which the change in stage height varied by over 1.5 m within a 3-h period. Typically these events are much less dramatic and ephemeral, with changes in water level varying by a few cm and lasting only a matter of hours. These short-period fluctuations are typically caused by winds, sudden changes in barometric pressure, seiches (which are oscillations caused by one or both of the former), and increased discharge of the river.

Additional influences on the hydrology of the St. Marys River are generated by commercial cargo ships as they ply the waterway (Alger 1979; Wuebben 1983; McNabb et al. 1986). Between 1970 and 1981, the number of times ships passed through the locks at Sault Ste. Marie ranged from a minimum of 11,059 in 1977 to a maximum of 13,991 in 1973. In recent years, the number of passages has decreased as older, smaller ships have been replaced by newer, larger ones. In 1981, 526 different ships used the locks (Liston et al. 1986); of those, 13 were of the largest size class that travel the Great Lakes (305 m long). Wuebben (1983) has modeled the effects expected on shoreline areas of the St. Marys River from the passage of those large ships. A principal effect of these, and of vessels of smaller size, is the creation of a water cycle in which there is a drawdown along adjacent shorelines as ships pass and then subsequent resurgence of water back into the area of drawdown.

An intensive study of the effects of ship passage at various wetland and one nonwetland site of the St. Marys River was undertaken during 1984 by McNabb et al. (1986). They categorized the various wetland sites studied (Figure 20) and estimated the drawdown that would occur if

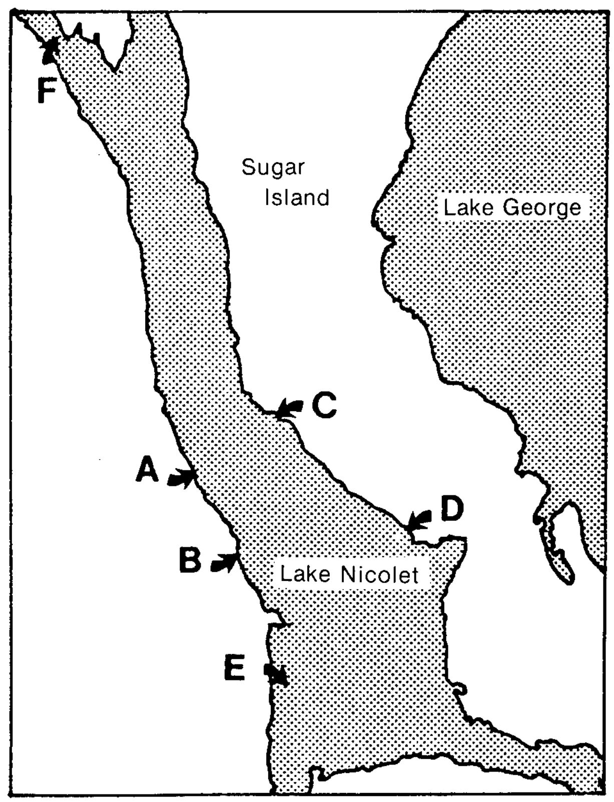


Figure 20. Sites of the St. Marys River monitored during commercial ship passages for the open-water period of 1984. A through E are emergent wetland sites; F is a nonemergent-wetland site (McNabb et al. 1986).

a 305-m ship moving at the existing speed limit passed those sites (Table 10). The estimates of drawdown are from Wuebben (1983) and the categorization is based on interpretation of oblique aerial photographs taken during November 1983 and earlier work on those wetlands by Liston et al. (1986).

At the sampling site for each ship passage, changes in water level, current direction, and velocity were measured. In total, 130 ship passages were monitored during 1984 (McNabb et al. 1986). A predictable pattern of water movement occurred at these six sites (Figure 20A-F) for many of those events. The water cycle illustrated in Figure 21 is applicable, in a generic sense, to water cycles created at other sites during various ship passages.

The water cycle associated with ship passage is divided into five phases: initial, standing wave, drawdown, surge, and postpassage (separated by dashed vertical lines in Figure 21). The first phase (initial) is characterized by little or no change in water level and ambient current velocities, which for this vessel passage were zero. In the second phase (standing wave), the water level increased and current velocities were detected for the first time. Currents generated were directed towards the shore, reached maximum velocity midway through the phase, then returned to zero. Drawdown began after the water level had reached its highest elevation, when currents were directed away from the wetland and towards the navigation channel. The greatest current velocity, 0.2 m/s, was noted in this phase. For other ship-passage events, maximum current velocities were usually noted during drawdown although some occurred during the next phase, the surge. Drawdown continued until the current direction reversed itself and flow was directed back towards the shore. This flow reversal began after the water level had reached its lowest point; this marked the beginning of the surge of water back into the wetland. The surge continued until current velocities diminished to almost zero and water level neared the baseline. The final phase of the water cycle (postpassage) was characterized by water-level fluctuations around the baseline and current velocities that exceeded ambient conditions. It was during postpassage that waves created by the wake of the passing ship crossed the sampling station. This cycle typifies water movements associated with ship passage for all of the events monitored during the study, but the magnitude of the various ship-induced phenomena varied considerably between events (McNabb et al. 1986). For

Table 10. Vegetational status of various emergent wetland sites of the St. Marys River and predicted vessel-passage effects. A disturbed vegetation pattern is one in which there are distinct disruptions within the emergent wetlands (McNabb et al. 1986).

Site[a]	Vegetation type	Vegetation pattern	Predicted drawdown (m)
A	Most-protected	Undisturbed	0.06
B	Most-protected	Disturbed	0.39
C	Least-protected	Disturbed	0.29
D	Most-protected	Undisturbed	0.20
E	Most-protected	Disturbed	0.49
F	None	--	0.30

[a]Sites refer to Figure 20.

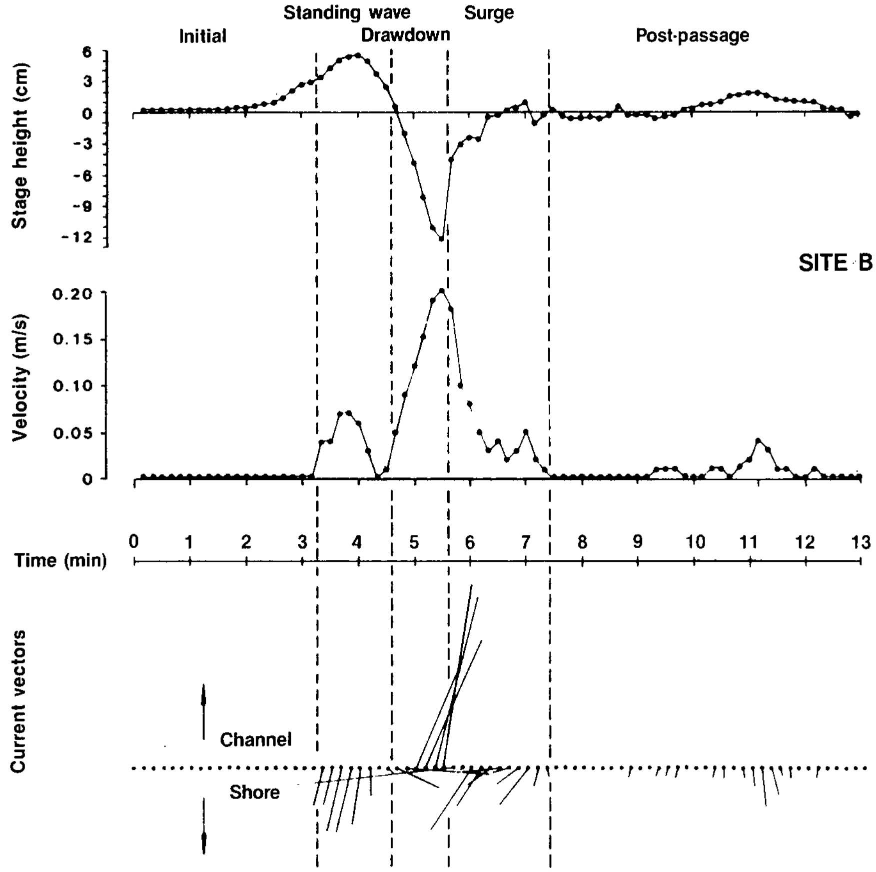


Figure 21. Water-level changes and current velocities generated by the upbound passage of the Ashley Lykes on 30 July 1984 at wetland Site B of the St. Marys River (McNabb et al. 1986).

the 130 ship-passage events, the greatest current velocities recorded were around 1.0 m/s, which is approximately the same as the fastest currents that have been measured in the river. The total change in water level within these sites ranged from 0.01 to 0.70 m. Overall, the influence of vessel passage on wetlands varied considerably from site to site.

No one factor dictates the extent to which water levels fluctuate and current velocities are generated. Factors such as vessel length, beam, draft, speed, and hull design, as well as distance from the wetland and basin morphometry, all contribute to the hydrological changes that plants experience as ships pass. The plants themselves probably also influence the extent and magnitude of these fluxes.

THE UNDERWATER REALM

Water Clarity

Water entering the St. Marys River is exceptionally clear for a large river in the Upper Great Lakes region. Calculated extinction coefficients for Upper Lake Nicolet for wavelengths between 400 and 700 ηm ranged from 0.35 to 0.94/m. These coefficients are a measure of the attenuation of light in a water column due to absorption by the water itself, dissolved compounds (e.g. organic acids, which color water shades of brown), suspended particulate matter, and scattering. Attenuation coefficients for Lake Nicolet and three lakes in Florida are presented in Figure 22. Dissolved organic substances that

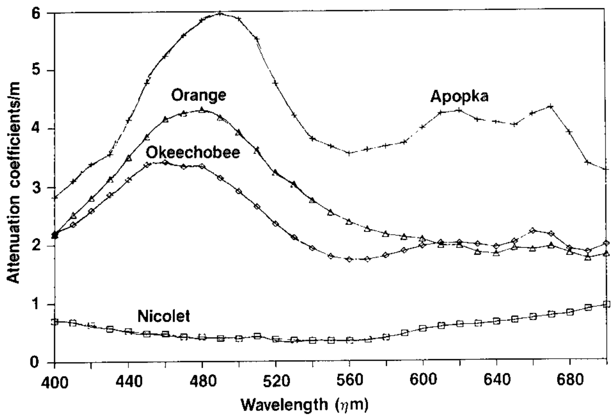


Figure 22. Attenuation coefficients for photons between 400 and 700 ηm for three lakes in Florida (Apopka, Orange, and Okeechobee) and Lake Nicolet (Batterson, McNabb, and Craig, unpubl. data).

color the Florida lakes brown absorb photons of light in the wave band around 480 to 500 ηm. These substances are not common in the waters of Lake Nicolet. The lake also does not contain suspended particulate matter that absorbs and scatters photons at wavelengths >560 ηm. It is apparent from these data that light is not attenuated as rapidly through the water column of Lake Nicolet as it is in the Florida lakes. Attenuation coefficients from Lake Nicolet are similar to those Schertzer et al. (1978) and Jerome et al. (1983) reported for Lake Superior.

Turbidity is the expression of the optical property that causes light to be scattered and absorbed. Water of the upper reaches of the St. Marys River has low turbidity, with values typically less than 1 nephelometric turbidity unit (NTU) (U.S. Geological Survey 1974-84; Liston et al. 1986). However, in downstream areas, clays in the watershed are mobilized by rain and snowmelt and are carried into the river by diffuse overland runoff and streamflow. The clay-laden plumes of major streams entering the river along the western shore are visually prominent during the ice-free season. A fraction of these clays settle out in downstream reaches of the river. In shallow deposition areas, clays are resuspended during periods of high wind and other turbulent conditions. Thus, water in western Munuscong Lake and along the southwest shore of Neebish Island are frequently turbid in the ice-free season, with measurements in excess of 50 NTU (Liston et al. 1986). When the watershed and river are covered with snow and ice, turbidity through the length of the river is low: on the order of 1 NTU.

During ice-free months inputs from the watershed, resuspension by waves at the shoreline, and currents combine to increase turbidity; turbidity levels increase as one proceeds downstream. This increase is least pronounced in main channel water that moves rapidly through the system. Here, turbidity increases average from 1 NTU to 7.5 NTU's from the head of the river through lower reaches to the mouth. Turbidity is higher in off-channel water in wide reaches of the river (Liston et al. 1986). Excluding the areas of localized high turbidity mentioned above, off-channel turbidity increases from 2 to 14 NTU between Lake Nicolet and Raber Bay of the river.

Submersed aquatic plants in the system are particularly sensitive to changes in light intensity that accompany increasing turbidity. These plants form extensive underwater meadows in the river where predominantly clay, rather than sand or cobble, sediments occur. The depth to which these meadows grow, and therefore the area which meadows can cover, is dependent on the availability of light. Light along the bottom of the river, where these plants germinate each year, decreases with increasing turbidity. Depth restriction of submersed meadow development by turbidity in the St. Marys River is shown in Figure 23. It is apparent from the shape of the curve in Figure 23 that even small changes in turbidity between 2 and 6 NTU's have a very large effect on the ability of species in the river to colonize the clay sediments available below a depth of 4 m. Thus, turbidity exerts a control on the amount of primary production that occurs in submersed wetlands.

Nutrients and Dissolved Gases

Data on alkalinity, pH, and dissolved oxygen are available for the St. Marys

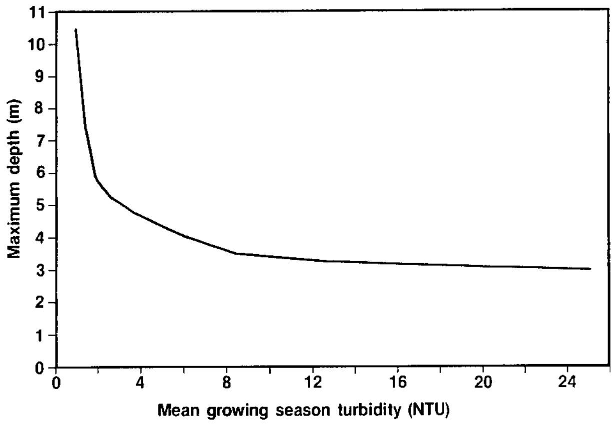


Figure 23. Relationship between maximum depth of boundaries of submersed meadows and mean turbidity in water over these boundaries during growing seasons of 1982 and 1983 in the St. Marys River. Left portion of the curve is for upstream locations and right portion is for downstream sites.

River from a number of sources (Upper Lakes Reference Group 1977; U.S. Geological Survey 1974-84; Liston et al. 1986). Results from these investigations are similar. Alkalinity is typically 40 mg $CaCO_3$/L (or 0.8 milliequivalents/L), pH ranges between 7 and 8, and dissolved oxygen concentrations vary seasonally, though the water is always more than 90% saturated. Dissolved oxygen concentrations throughout the river are adequate to support all forms of aquatic life (Liston et al. 1986) and are well above the 5.0 mg/L the U.S. Environmental Protection Agency recommends for supporting fish populations (Brungs 1977).

The concentration of carbon dioxide that is dissolved in water is important to phytoplankton and submersed macrophytes for photosynthesis. Calculations of free CO_2 can be made if one knows the temperature of the water, pH, and alkalinity (see Wetzel 1983). Using an atmospheric value of 0.033% CO_2 by volume, equilibrium concentrations for CO_2 dissolved in the river would be about 1.1 mg CO_2/L at 0 °C, 0.6 mg CO_2/L at 15 °C, and 0.4 mg CO_2/L at 30 °C. Free CO_2 concentrations calculated from data collected by Liston et al. (1986) were always greater than concentrations which would be in river water in equilibrium with the atmosphere. This indicates that phytoplankton and submersed plants in the river use less CO_2 than is produced by respiration of organisms in the system; that is, the river is a heterotrophic system (Odum 1971). Light-dark bottle oxygen studies in the Lake Nicolet reach of the river demonstrated the heterotrophic nature of the system as well (McNabb et al. unpubl. data).

Liston et al. (1986) report concentrations of silica (dissolved reactive SiO_2) in the open waters of the St. Marys River. Silica concentrations were always one order of magnitude greater than the concentration reported in the literature to be limiting to growth of the planktonic diatoms which dominate macrophytoplankton of this system (100 mg/m^3 or less; Wetzel 1983). Silica concentrations tended to vary seasonally such that spring and fall minima and summer maxima existed (Liston et al. 1986). Schelske and Stoermer (1971) and Schelske et al. (1983) described the principal mechanism for silica reduction in growing seasons as removal by diatoms. In the St. Marys River, silica removal may have been accomplished upstream of sampling points by diatoms in the plankton of Whitefish Bay, or by benthic diatom communities and littoral periphyton populations in reaches of the river. Silica concentrations ranged from 980 to 3,660 mg/m^3 with a mean of 2,181 mg/m^3 for the years 1982 and 1983 (Liston et al. 1986). This is very close to the mean concentration of 1,840 mg/m^3 reported by Schelske and Callender (1970) for three stations in Whitefish Bay. These data show that silica was not a limiting nutrient for diatom production in the St. Marys River.

Total nitrogen (TN) ranged from 262 to 668 mg/m^3 (average = 413 mg/m^3), while total phosphorus (TP) ranged from 1 to 31 mg/m^3 (average = 13 mg/m^3) during 1982 and 1983 (Liston et al. 1986). Total phosphorus concentrations reported by Liston et al. (1986) are similar to values presented by the Upper Lakes Reference Group (1977) and the U.S. Geological Survey (1974-84). Sakamoto (1966), Chiaudani and Vighi (1974), and Smith and Shapiro (1981), among others, have shown

that the ratio of TN to TP in the photic zone is a useful index for separating lakes into N-limited and P-limited categories. Their work predicted that if the TN:TP ratio was >10, algal production was likely to be phosphorus-limited. The TN:TP ratio for the St. Marys River varied during the growing season, averaging 32 but always exceeding 10 (Liston et al. 1986); this suggests that in regard to these two mineral nutrients, growth of planktonic algae was limited by phosphorus rather than nitrogen.

Wetzel (1983) reports ranges for TN and TP concentrations typical of eutrophic, mesotrophic, and oligotrophic pelagic waters of reservoirs and lakes. In oligotrophic waters, TN ranges from 307 to 1,630 mg/m^3 and TP ranges from 3 to 17.7 mg/m^3. Samples from the St. Marys River always had concentrations of TN within the given range, while TP concentrations were within their given range more than 68% of the time, indicating the oligotrophic nature of these waters.

Contaminants

The water quality of the St. Marys River is generally quite excellent and basically resembles that of Lake Superior (Hamdy et al. 1978). However, the Great Lakes Water Quality Board (1985) has identified the river as one of 42 areas of concern within the Great Lakes in which environmental quality has been degraded and beneficial uses of the water and the biota have been adversely affected. It was not included on the list of "problem areas" until 1974 even though elevated concentrations of phenols had been recognized as early as the 1940's (Great Lakes Water Quality Board 1985). There have been many sources of contamination to the river, all the result of human activity in the vicinity of Sault Ste. Marie. These sources include municipal wastewater treatment facilities, combined sewer overflows, industrial discharges, commercial cargo vessel discharges, and urban nonpoint run-off. Many of the problems have been rectified and water quality in general has improved since the late 1960's (Hamdy et al. 1978).

Presently, the problems are restricted to the Canadian shore and are mainly the result of discharges from the Sault Ste. Marie, Ontario, sewage treatment plant, Algoma Steel Corporation, and the Abitibi Paper Company. Natural and human constraints have minimized flows along the Canadian side of the river and, coupled with the lateral discharge from the Sault Edison Hydroelectric Power Canal on the Michigan side, have tended to confine the contaminants to the Ontario shoreline (Hamdy et al. 1978; Great Lakes Water Quality Board 1985). In the past, some of the contaminants have been detected at elevated levels as far down-stream as the outlet of Lake George (Lake Huron-Lake Superior-Lake Erie Advisory Board 1968). Contaminants that continue to be of concern include toxic substances such as phenols, ammonia, cyanide, and heavy metals (chromium, copper, iron, lead, mercury, zinc), oil and grease mixed with fibrous woody material, and bacteria (fecal coliforms, fecal streptococci, heterotrophic types, and *Pseudomonas aeruginosa*). Some remedial actions to combat these problems have been implemented and others are to follow which will be closely monitored by the Great Lakes Water Quality Board (1985).

CHAPTER 3. THE BIOTA

PRIMARY PRODUCERS

Emergent Wetlands

Throughout the length of the St. Marys River, a series of constricted channels and broad lake-like vistas await the voyager. Except near the cities of Sault Ste. Marie, long stretches of shoreline are without homes or commercial development. Rocky shores are found in constricted reaches of the river where current velocities are high. Elsewhere, clay mixed with a variable fraction of sand and organic detritus forms a hydrosoil that slopes gently away from the land toward navigation channels. Unoccupied shorelines with fine-grained hydrosoil tend to be inhabited by emergent vegetation. Stands of emergent vegetation are particularly well-developed where wind and waves are not a prominent feature of the shore-zone environment. It is not uncommon for stands of emergent plants to extend uninterrupted along protected shores for 3 to 5 km. Some 42 species of submersed and emergent plants occur in the zone of permanent water in these wetlands (Table 11).

Annual production of biomass in wetlands facing on the river is dominated by three emergent plants: Scirpus acutus, Sparganium eurycarpum, and Eleocharis smallii (hardstem bulrush, bur reed, and spike rush, respectively). Submersed species occur as a diffuse understory of low biomass. Seeds of the dominant emergent species germinate on wet soils near the shoreline, rather than in permanently flooded portions of wetlands. Species become dominant by the spread of rhizomes from successful colonizers outward from the shore. As a result of such growth, rhizomes and roots become a tightly packed fibrous mesh in the upper 15 cm of soil throughout emergent wetlands.

Vegetative and clonal growth produces and maintains emergent wetlands on the St. Marys River and gives rise to monotypic stands of emergent species; these are more common than mixed stands of emergent plants in the St. Marys wetlands. Aerial photographs taken over the last 3 decades indicate that clones of dominant species tend to be long-lived. These clones have maintained their position relative to one another in these wetlands so that the structure of emergent vegetation has been a relatively permanent feature of the undisturbed shorelines for at least 30 years. It is of interest to note that Phragmites australis (common reed) and Typha latifolia (common cattail), species that are aggressive and well-established elsewhere in the Great Lakes region, are present only in small stands in drier, shoreward portions of wetlands along the St. Marys River. These clones may have been established from seed late in the process of wetland development, or existing clones may be remnants of stands that have been replaced by the dominant species of today.

Individual wetlands bordering the St. Marys River have their own peculiarities in terms of distribution and abundance of dominant vegetation. However, a generalized picture of their structure can be obtained by combining detailed maps of seven wetlands selected as representative of those occurring along the river (Liston et al. 1986). These maps cover a combined total area of 167 ha in the wetlands. Table 12 lists types of dominant vegetation in these systems and suggests the probability of encountering particular types of vegetation while traversing these wetlands.

Scirpus acutus is clearly the dominant plant in shore-zone wetlands. While clones of this plant occur at all water

Table 11. Species list of macrophytes in permanently flooded portions of emergent wetlands (mean growing season depth of 3.0 m or greater) of the St. Marys River (Liston et al. 1986).[a]

Species	Common name
Acorus calamus	sweet-flag
Alisma plantago-aquatica	water plantain
Carex retrorsa	sedge
Dulicium arundinaceum	three-way sedge
Eleocharis acicularis	needle rush
Eleocharis pauciflora	spike rush
Eleocharis smallii	spike rush
Equisetum fluviatile	horsetail
Eriocaulon septangulare	pipe wort
Hypericum boreale	St. John's wort
Isoetes braunii	quillwort
Isoetes riparia	quillwort
Juncus balticus	rush
Juncus brevicaudatus	rush
Juncus effusus	rush
Juncus pelocarpus	rush
Myriophyllum exalbescens	watermilfoil
Nuphar variegatum	yellow water lily
Phragmites australis	common reed
Polygonum natans	smartweed
Pontedaria cordata	pickerel weed
Potamogeton gramineus	variable pondweed
Potamogeton natans	floating-leaf pondweed
Potamogeton pectinatus	sago pondweed
Potamogeton richardsonii	clasping-leaved pondweed
Potamogeton spirillus	pondweed
Potamogeton zosteriformis	flat-stemmed pondweed
Ranunculus flabellaris	yellow water crowfoot
Ranunculus reptans	buttercup
Sagittaria engelmanniana	arrowhead
Sagittaria latifolia	duck potato; wapato
Scirpus acutus	hardstem bulrush
Scirpus americanus	three-square bulrush
Scirpus validus	softstem bulrush
Sparganium americanum	bur reed
Sparganium chlorocarpum	bur reed
Sparganium eurycarpum	bur reed
Sparganium fluctuans	bur reed
Typha angustifolia	narrow-leaved cattail
Typha latifolia	common cattail
Utricularia cornuta	bladderwort
Vallisneria americana	water celery; tape grass

[a]The taxonomy follows that of Voss (1972) where possible or Fassett (1957) if not included in Voss.

Table 12. Generalized occurrence of vegetation types that dominate biomass in emergent wetlands of the St. Marys River (McNabb et al. 1986).

Vegetation type	Fraction of wetland occupied
Monotypic stands	
Scirpus acutus	0.46
Sparganium eurycarpum	0.11
Eleocharis smallii	0.05
Phragmites australis	0.01
Scirpus americanus	0.01
Typha latifolia	0.01
Mixed stands	
S. acutus/E. smallii	0.12
S. acutus/S. parganium *S. eurycarpum*	0.03
Other mixed stands	0.04
Opening in emergent stands	0.15

depths in the wetlands, its presence in monotypic stands on wetland fringes facing the river is a distinctive feature of St. Marys River vegetation. Secondary species, *Sparganium eurycarpum* and *Eleocharis smallii*, are confined to water more shallow than typically found at the *Scirpus acutus* fringe. There are sites along the river where the *S. acutus* fringe has died back, leaving *Sparganium eurycarpum* on the exposed wetland edge (Figure 24). Stands of *S. eurycarpum* do not appear well adapted to water movements that occur on these exposed outer edges of wetlands and are eroding.

A

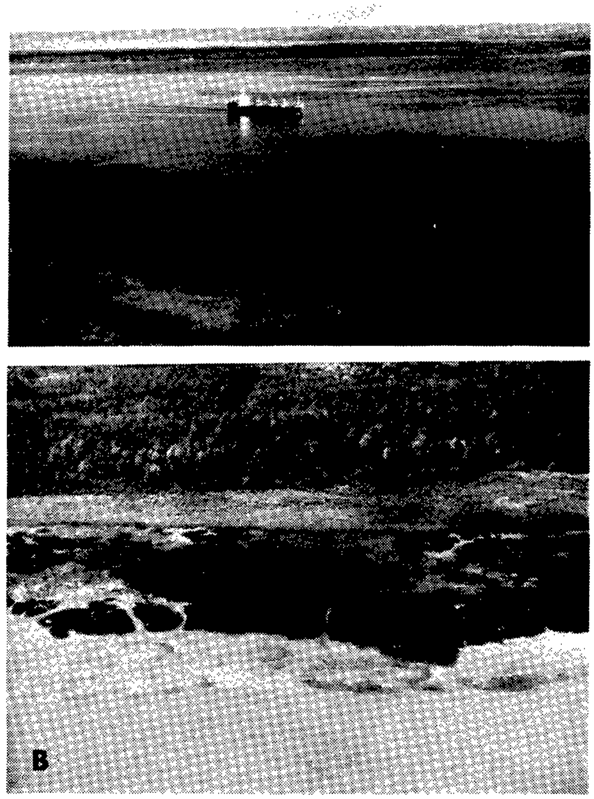


Figure 24. An emergent wetland on the St. Marys River: (A) undisturbed portion showing a well-developed stand of the hardstem bulrush on the outer wetland fringe, and (B) adjacent section with eroding bur reed on the outer fringe behind rootstock remnants of the bulrush (Liston et al. 1986). (Photograph courtesy of Clarence D. McNabb.)

There are seasonal changes in the abundance of vegetation in the shore zone of the St. Marys River. Generalized patterns for annual abundance of live rootstocks and shoots of *Scirpus acutus* are shown in Figure 25. *Sparganium eurycarpum*, *Eleocharis smallii*, and *Phragmites australis* were observed to have patterns of biomass abundance similar to that of the *Scirpus acutus*.

Figure 25 shows that rootstocks of dominant emergent plants are present in the hydrosoil year round. They reach maximum biomass late in the growing season, about October 1. Portions of root stocks degenerate in winter. After ice leaves emergent wetlands in spring, hydrosoils warm and rootstocks prepare for the surge of a new growing season. Buds on rootstocks germinate to form shoots: cell division and enlargement in the hydrosoil at the base of the shoot push it upward into the light, and eventually above the water surface into the air. Live rootstocks die back rapidly during this freshening of the wetland, apparently yielding their food and nutrient reserves to new shoot growth. A tight cycling of nutrients results from this and leaves few

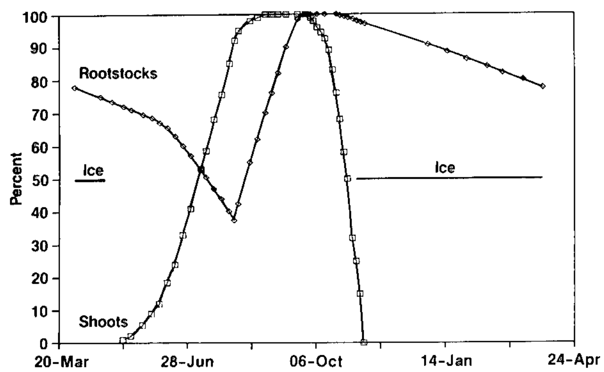


Figure 25. Annual cycle of live biomass (organic dry weight) in stands of hardstem bulrush (Scirpus acutus) in the St. Marys River expressed as a percent of seasonal maximum standing crop.

nutrient resources available in stands for invading species, particularly in this oligotrophic system.

Shoot growth from warm hydrosoils is rapid in June and July. As shoots approach maximum biomass in August, photosynthetic food resources are allocated to the growth of rootstocks. As shown in Figure 25, rootstocks increase from an annual minimum in midsummer toward their maximum in late September. Table 13 gives estimates of biomass for emergent plants at maturity in the fall and distribution of biomass between shoots and rootstocks. It can be observed that the annual cycle of plant growth in these wetlands protects shore-zone sediments from erosion. A high density mesh of rootstocks occurs in the surface of the clay hydrosoils, except in summer when shoots are present to dissipate the energy of waves and currents that may move over the hydrosoil.

An observer traversing emergent wetlands of the St. Marys River during the first few weeks after ice-out would come upon decaying stalks of Scirpus acutus standing upright in the water, bases planted firmly on the sediments, tops broken at the waterline and gone, forming windrows upon which noisy black terns (Chlidonias niger) nest. Underwater stalks would be clearly visible in the clean, shallow water, and covered with a delicate fuzz, perhaps 5-mm thick, that collapses into a thin layer of slime when a stalk is pulled from the water. This is the periphyton of emergent wetland plants, a mix of micro-organisms covering the

Table 13. Biomass in monotypic stands of dominant emergent plants in wetlands of the St. Marys River at time of peak standing crop (September-October). AFDW = ash-free dry weight.

Species	Total live biomass (g AFDW/m^2)	Live shoot/root biomass ratio
Scirpus acutus[a]		
Low density	1,340	0.2
Medium density	1,620	0.5
High density	3,540	2.2
Sparganium eurycarpum	1,830	0.4
Eleocharis smallii	600	0.7
Phragmites australis	2,000	0.2
Scirpus americanus	320	0.5

[a]Liston et al. (1986) distinguished three densities by assessment of aerial photographs and ground-truth measurements of shoots/m^2 and leaf area/m^2.

underwater surfaces of macrophytes. Autotrophs in this community are species of diatoms. An array of single-celled and colonial heterotrophs is common as well (Figure 26).

The periphyton community found on stalks in emergent wetlands develops in a relatively short period of time after ice-out because of the growth habits of emergent plants. Surfaces of S. acutus and other dominant macrophytes are pushed continually upward and out of the water as plants grow. The portion of a stalk on which an ice-out community resides is not permanently in place until the stalk stops growing in August. Two or three months of late summer and fall follow before ice begins to form around stalks and their periphyton. After ice-out, light and some warmth return to the wetland, but the community has little time for development; stalks will crumble and decay in the warm water of the weeks ahead. Overwintering periphyton survivors will join the species mix on the sediment surface, perhaps to produce progeny that will rise again into the water column on the epidermis of a growing bulrush. Early arrivals, however, will have little time to profit in their new found space. In a matter of days after attaching to a stalk, they will be pushed upward through the air-water interface into a desiccating environment.

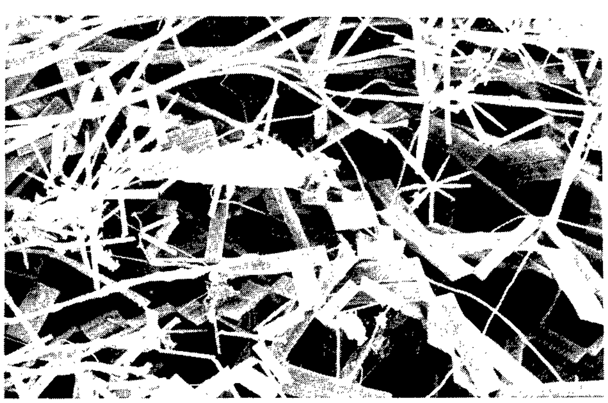


Figure 26. Electron micrograph of diatoms and colonial heterotrophs of the periphyton community in emergent wetlands of the St. Marys River. The length of the line is 100 microns. (Photograph courtesy of John R. Craig.)

Only late arrivals on new basal tissue have any kind of longevity on plant stalks. And so the periphyton community goes from year to year in spurts of development that are interrupted by desiccation in the air, ice in winter, or collapse of overwintering shoots in spring.

In this changing community, Liston et al. (1986) found mean net periphyton productivity in the growing seasons of 1982 and 1983 to range from 20 to 40 mg C/m^2 of emergent plant surface per day on different emergent species on different sites along the river. The mean for all measurements was 32 mg C/m^2 of plant surface per day. By their methods of conversion from carbon to organic dry weight, this amounted to approximately 9 g ash-free dry weight net production per m^2 of plant surface over the duration of ice-free months of the year, May through October.

The area on emergent plant stems available for colonization varied both seasonally and among plant species (Liston et al. 1986). For example, stands of Scirpus acutus of different densities growing in 0.7 m of water had 1-9 m^2 of surface for periphyton colonization per m^2 of wetland when stands were mature in late summer. However, in June, early in the growing season, only 7%-10% of this area was available for colonization. Sparganium eurycarpum had 6-8 m^2 of surface for periphyton per m^2 of wetland in mature stands in late summer in water 0.4 m deep. These authors used underwater shoot area per unit area of wetland to estimate annual growing season periphyton productivity at about 12 g ash-free dry weight per m^2 of wetland. This amounted to only 2% of the annual production of shoots of emergent plants on which the periphyton grew.

Submersed Wetlands

Upstream of the river's fork at Mission Point and through Lake Nicolet and its downstream reaches, submersed wetlands spread as meadows of low-growing plants over bottom sediments where the river is broad, substratum is suitable, and water clarity is good (Liston et al. 1986; McNabb et al. 1986). There is, however, virtually no information on submersed wetlands in Lake George of the St. Marys River (Liston et al. 1983).

Twenty-two species of plants have been documented in the submersed wetlands of the St. Marys River (Table 14). However, three species dominate biomass in submersed stands: Chara globularis (charophyte), Isoetes riparia (quillwort), and Nitella flexilis (charophyte). These are low-growing plants, rising 10-30 cm above the sediment surface. In narrow channels, meadows tend to carpet sediments from edges of navigation channels shoreward. The shoreward depth limit of submersed meadows is about 2 m. From the water's surface, low-growing meadows of these plants at a depth of 2 m or more are not obvious to the casual observer. More impressive are very widely scattered clusters of the pondweed, Potamogeton richardsonii, which punctuate the meadows and rise to the surface of the water from as deep as 2.5 m. However, submersed meadows of dominant low-growing species are much more widespread and are impressive indeed when one is snorkeling or using SCUBA.

Beds of dominant submersed macrophytes are found on predominantly clay sediments that contain various fractions of sand and silt. Clays on slopes of dredged navigation channels are occupied, as are broad clay flats common in the river. Extensive sand benches occur in portions of the river at depths <2 m. The sand shifts under the influence of currents and waves, thereby creating an inhospitable substratum for permanent submersed plant colonization. Cobble and rock sediments are not occupied by submersed macrophytes. These substrates are generally devoid of

Table 14. Species list of macrophytes in submersed wetlands of the St. Marys River (Liston et al. 1986; McNabb et al. 1986).[a]

Species	Common name
Chara globularis	charophyte
Eleocharis acicularis	needle rush
Eleocharis canadensis	northern elodea
Isoetes riparia	quillwort
Lobelia dortmanna	water lobelia
Myriophyllum exalbescens	water milfoil
Myriophyllum tenellum	water milfoil
Najas flexilis	bushy pondweed
Nitella flexilis	charophyte
Potamogeton gramineus	variable pondweed
Potamogeton filiformis	pondweed
Potamogeton pectinatus	sago pondweed
Potamogeton praelongus	whitestem pondweed
Potamogeton richardsonii	clasping-leaved pondweed
Potamogeton robbinsii	Robbins' pondweed
Potamogeton zosteriformis	flat-stemmed pondweed
Ranunculus reptans	buttercup
Sagittaria cuneata	arrowhead
Sagittaria engelmanniana	arrowhead
Tolypella intricata	
Utricularia cornuta	bladderwort
Vallisneria americana	water celery; tape grass

[a]The taxonomy follows that of Voss (1972) where possible or Fassett (1957) if not included in Voss. The charophytes follow the taxonomy set forth in Wood (1967).

microalgae as well. Macroscopic filamentous algae (Family Zygnemataceae) are seasonal. They appear at low biomass along shorelines and in submersed vegetation shortly after ice-out.

Stands of Isoetes riparia are virtually monotypic in distribution and are never the deepest stands occurring on a site occupied by submersed plants. Beds of I. riparia are confined to depth contours of 2-3.5 m. Nitella flexilis occupies the deepest portions of submersed wetlands on suitable sites along the river. Monotypic stands of this species extend to depths of 16 m at the head of the river (Duffy et al. 1985) and 3 m in the reach below Munuscong Lake (Liston et al. 1986). Stands of Chara globularis occur in more shallow water than stands of N. flexilis in reaches of the river where they both occur. Stands of C. globularis may be monotypic or mixed with N. flexilis. Eleocharis acicularis (needle rush) and Myriophyllum tenellum (water milfoil) are common in submersed meadows. They are very small plants and contribute little to biomass. In the St. Marys River, the common species of submersed wetlands are typical of nutrient-poor rather than nutrient-rich environments.

Lake Superior water moving downstream tends to be well dispersed over submersed meadows, even in broad reaches of the river. This causes temperatures in the meadows to be lower than temperatures in the shallows of adjacent shorelines from ice-out to August (see Figure 15). Onset of plant germination in submersed meadows is delayed by low temperatures in spring relative to vegetation in shore zones.

In recent times, submersed meadows in various portions of the St. Marys River have maintained their boundaries, species composition, and characteristic biomass between years (Liston et al. 1986). This occurs because dominant species tend to be perennial. Isoetes riparia maintains rosettes of leaves year round on individual plants firmly rooted in sediments. Shoots of charophytes persist in stands year round as well. Shoots of these plants have a fine meshwork of rhizoids that anchor them to the sediments. When water temperatures in wetlands reach 5-6 °C, generally near June 1, new growth appears on overwintering plants: leaves on rosettes of I. riparia and shoots from rhizoidal bulbils (nodules) and old shoots of charophytes. A new standing crop in a growing season develops more rapidly in warm than in colder parts of the system. Lag-time on cold sites can be as much as 2-3 weeks. As new shoots of charophytes grow, overwintering biomass in meadows degenerates to detritus and is sloughed or mineralized at a rate nearly equivalent to the rate of new tissue accumulation. As new leaves are formed on rosettes of I. riparia, older leaves decompose at a similar rate. New rosettes are also produced within stands of I. riparia from fertilized megaspores. These become established late in the growing season but contribute little biomass in the year of their formation. Thus, growth and decomposition occur in meadows such that relatively constant biomass is maintained throughout the growing season. This characteristic of submersed wetlands of the river is illustrated in Figures 27 and 28. The pattern shown in the figures can be disrupted on a particular site if patches of vegetation tear loose from the sediments and drift downstream.

Monotypic and mixed stands of dominant submersed plants on sites sampled in the river had a mean peak biomass in the range

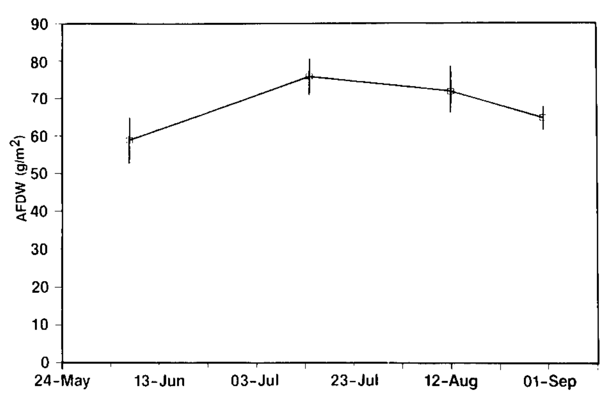


Figure 27. Growing season biomass of the quillwort, Isoetes riparia, in a monotypic stand in the Neebish Island region of the St. Marys River in 1981. One standard error of the mean is given (Liston et al. 1986).

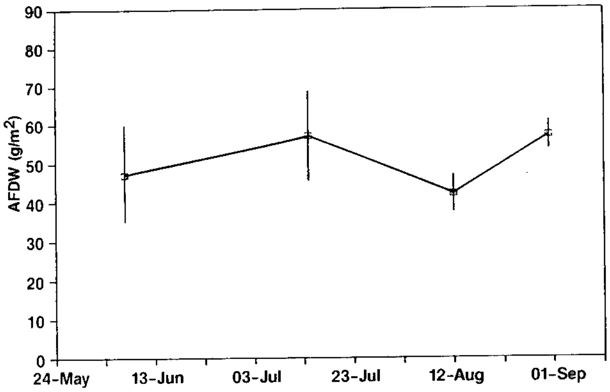


Figure 28. Growing season biomass of charophytes (95% *Nitella flexilis*, 5% *Chara globularis*) in a stand in the Neebish Island region of the St. Marys River in 1981. One standard error of the mean is given (Liston et al. 1986).

of 10-70 g ash-free dry weight/m^2 during 1979-83 (Liston et al. 1986). The mean of all samples from all sites in 1979-83 was 36 g ash-free dry weight/m^2 (Liston et al. 1986). This range and mean of seasonal maximum biomass is low relative to more fertile lakes and streams. Wetzel (1983) reports biomass in the range of 200-500 g ash-free dry weight/m^2 for submersed stands in nutrient-rich waters.

Phytoplankton

The knowledge of St. Marys River phytoplankton is limited and fails to take into account the total phytoplankton community, which includes nannoplankton and microalgae as well as net plankton. Most of the work consists of qualitative and semiquantitative counts restricted to diatoms and other macroplankton. Briggs (1872) was the first to publish on the phytoplankton of the St. Marys River. Since that early work, monitoring studies have been conducted below the head of the river by the National Water Quality Network (1960-64), the Ontario Ministry of the Environment (Upper Lakes Reference Group 1977), and the U.S. Geological Survey (1974-84). Liston et al. (1981, 1983, 1986) have also studied the macrophytoplankton of the St. Marys River. Diatoms dominate the flora, and the species that are present characterize oligotrophic waters, similar to reports for Lake Superior (Schelske et al. 1972; Feldt et al. 1973; Vollenweider et al. 1974; Munawar and Munawar 1978). Other algal groups that have been identified in the phytoplankton of the river include phytoflagellates (Chrysophyceae, Cryptophyceae, and Dinophyceae), greens, and blue-greens.

In 1982, 72 species of diatoms were identified in the Lake Nicolet reach of the river, representing 26 genera and 11 families (Liston et al. 1986). The 14 most common diatoms of that study are listed in Table 15. Life habits as defined in Hutchinson (1967) and Patrick (1977) indicate that of those species presented in Table 15, *Asterionella formosa*, *Cyclotella comta*, *Cyclotella glomerata*, *Fragilaria crotonensis*, *Melosira islandica*, *Stephanodiscus hantzschii*, and *Synedra ulna* are truly planktonic. *Achnanthes minutissima* is the only benthic species listed in Table 15, but many of the 72 species reported in Liston et al. (1986) also had benthic affinity. These species were apparently dislodged from the bottom and swept up into the plankton by currents. Such a mix of typically planktonic species with those that are benthic in habit was also observed by Kreis et al. (1983) in the plume of the St. Marys River in Lake Huron. Benthic populations comprised as much as 40% of the total algal

Table 15. The most common diatoms in the Lake Nicolet reach of the St. Marys River during 1982 (Liston et al. 1986). The taxonomy follows that of Patrick and Reimer (1966) and Weber (1971).

Achnanthes minutissima
Asterionella formosa
Cyclotella comta
Cyclotella glomerata
Cyclotella kutzingiana
Fragilaria construens
Fragilaria crotonensis
Melosira islandica
Rhizosolenia eriensis
Stephanodiscus hantzschii
Synedra acus
Synedra nana
Synedra ulna
Tabellaria fenestrata

assemblage in terms of cell volume, while the remainder were truly planktonic in occurrence.

Chlorophyll *a* concentrations measured by Liston et *al.* (1986) indicated that planktonic algal biomass varied only slightly between upstream and downstream reaches of the St. Marys River during ice-free months. The mean chlorophyll *a* concentration was 0.88 mg/m^3, which falls within the range 0.3-3.0 mg/m^3 typical of oligotrophic waters (Wetzel 1983). This value is also very close to concentrations reported by Vollenweider et al. (1974), Watson et al. (1975), El-Shaarawi and Munawar (1978), for waters of Lake Superior which are classified as being oligotrophic.

Similar to chlorophyll *a* concentrations, primary productivity of the plankton of the river is within the range associated with oligotrophy. Wetzel (1983) reports a range of mean net productivity, measured by radioactive carbon methods, of <50 mg C $\cdot$ m^{-2} $\cdot$ day^{-1} and 50 to 300 mg C $\cdot$ m^{-2} $\cdot$ day^{-1} for ultraoligotrophic and oligotrophic waters, respectively. The range of measurements reported by Liston et al. (1986) was 56.5 to 58.9 mg C $\cdot$ m^{-2} day^{-1}.

Overall, the species composition, biomass, and productivity of the phytoplankton of the St. Marys River are very similar to that of Lake Superior. However, there is an important difference between those two environments: in the river, the phytoplankton community is transient, since it is constantly being transported downstream at a relatively rapid rate.

Annual Productivity of the Primary Producers

During 1982-83, Liston et al. (1986) made measurements to determine the relative importance of emergent wetlands, submersed macrophyte communities, and phytoplankton as food-producing components of the St. Marys River ecosystem. Data from seven emergent wetlands from the head of the river downstream were treated to yield an estimate of annual productivity for the average m^2 of all dominant species combined. Estimates for the average m^2 of submersed macrophyte meadows and open-water phytoplankton habitat were made as well. These data are given in Table 16 and show that emergent plants on an areal basis were by far the most productive component of the river system: some 200 times more productive than phytoplankton and 40-50 times more productive than submersed plants. Periphyton on submersed shoots of emergent wetland plants had annual productivity on the same order as that of the phytoplankton. Thus, in the St. Marys system, food production for consumers was concentrated along edges of the river in emergent wetlands and along the bottom in submersed plant communities. The optimum foraging theory (Werner et al. 1983a, b) suggests that these areas of high food density are not ignored by mobile invertebrate and vertebrate consumers. While phytoplankton productivity is low and food particles for plankton grazers are widely spaced in the water column, relatively large quantities of phytoplankton are carried daily through the riverine habitats of stationary filter-feeding invertebrates, such as net-building caddisfly larvae and clams, by water masses moving downstream.

Table 16. Aerial net annual primary productivity[a] of plant communities in the St. Marys River (Liston et al. 1986).

Community type	g AFDW $\cdot$ m^{-2} $\cdot$ yr^{-1}
Phytoplankton	7
Submersed macrophytes[b]	35
Emergent wetlands	
Shoots	650
Periphyton	12
Rootstocks	930

[a] Ash-free dry weight (AFDW).
[b] Periphyton of submersed macrophytes not included. Submersed plants have little periphyton except during decomposition phase in summer.

SECONDARY PRODUCERS

Zooplankton

Zooplankton of freshwater ecosystems represent an important link between phytoplankton and higher trophic levels. Phytoplankton in the pelagic zone of lakes and rivers are minute in size and have a low standing stock-biomass; however, they constitute the basis of pelagic food webs by virtue of their characteristically rapid turnover times (Kerfoot and Dermott 1980). Zooplankton concentrate the energy available as phytoplankton biomass into larger particles which are then available to fish and other planktivorous feeders. The importance of zooplankton to both adult and juvenile planktivorous fish has been documented for several decades (Wells 1970; Hall et al. 1970; Werner and Hall 1974). Despite their importance, few studies of the St. Marys River zooplankton have been undertaken.

Thirty species of zooplankton empty into the river from Whitefish Bay (Selgeby 1975). Of these, nine species of copepods and three species of cladocerans were common (Table 17). Calanoid copepods accounted for 50% of the total number of zooplankton collected, cyclopoid copepods 40%, and cladocerans the remaining 10%. Seasonally, the winter zooplankton community consisted primarily of adult stages of Diaptomus sicilis, Diaptomus ashlandi, and Limnocalanus macrurus, and immature copepodids of Cyclops bicuspidatus thomasi (Figure 29). During summer, immature calanoids, adult Cyclops bicuspidatus thomasi, and Cladocera predominated in the open-water environment.

The zooplankton community of the lower river was sampled by Thomas and Liston (1985) near Raber Bay. They report a zooplankton community very similar in species composition to the summer community found by Selgeby (1975) in the upper river, but far less abundant (Table 17). However, Thomas and Liston (1985) utilized a net with 351 µm mesh openings, which would be expected to capture only adult stages or larger individuals, whereas Selgeby (1975) sampled with a 120 µm mesh net.

Table 17. Species of zooplankton collected from the St. Marys River and average abundance in each of four separate habitats (Selgeby 1975; Duffy 1985; Thomas and Liston 1985).

Species	Number/m³ Rapids area	Navigation channel	Open water nearshore	Number/L Emergent macrophyte bed
COPEPODA				
Cyclopoida				
Cyclops bicuspidatus thomasi	1,556	5	6	
Cyclops vernalis	5	2	143	
Cyclops strenuus	<1			
Macrocyclops albidis	<1			137
Mesocyclops edax	32	2	1,272	
Calanoida				
Diaptomus ashlandi	1,091	25	41	
Diaptomus minutus	105	1	7	
Diaptomus oregonensis	<1			
Diaptomus sicilis	803	207	61	
Epischura lacustris	7	12	4	

(Continued)

Table 17. (Concluded)

Species	Number/m³ Rapids area	Navigation channel	Open water nearshore	Number/L Emergent macrophyte bed
COPEPODA (continued)				
Calanoida (continued)				
Eurytemora affinis		<1		
Limnocalanus macrurus	33	163	16	
Senecella calanoides	9	4		
CLADOCERA				
Acroperus harpae	<1			365
Alona costata	<1			
Alona guttata	<1			92
Alona exigua				5
Alona intermedia				11
Alona quadrangularis				29
Alona rectangularis				87
Alonella acutirostris	<1			46
Bosmina longirostris	187	13	6	13
Camptocercus rectirostris				64
Ceriodaphnia lacustris			<1	
C. megalops				<1
Ceriodaphnia quadrangula				41
Chydorus gibbosus	<1			3
Chydorus sphaericus	<1			1,042
Daphnia galeata mendotae	169	5	5	
Daphnia retrocurva	39	73	3	
Diaphanosoma leuchtenbergianum	<1			
Eurycercus lamellatus	<1	5	13	106
Graptoleberis testudinella				29
Holopedium gibberum	<1	88	22	
Ilyocryptus spinifer				<1
Lathonura rectirostris				7
Latona parviremus			<1	
Leptadora kindtii	<1	1	92	
Macrothrix rosea				<1
Pleuroxus denticulatus				32
Pleuroxus procurvus	<1			38
P. truncatum				<1
P. uncinatus				<1
Polyphemus pediculus	<1	2	1	3
Ophryoxus gracilis				<1
Rhynchotalona falcata	<1			<1
Sida crystallina	<1	7	138	44
Simocephalus serrulatus				222
OSTRACODA				201

In contrast to the pelagic or open-water community, the zooplankton of emergent wetlands are almost entirely Cladocera (Duffy 1985). Furthermore, the maximum density of zooplankton within emergent wetlands is more than an order of magnitude greater than the maximum densities found in open water. The most abundant species within wetlands were Chydorus sphaericus and Acroperus harpae (Table 17), which are both quite small. Common species which are larger and probably important with respect to standing stock biomass included Macrocyclops albidis, Eurycercus lamellatus, and Sida crystallina as well as Ostracoda. Of the 29 species of zooplankton found in emergent wetlands by Duffy (1985), nine were considered rare.

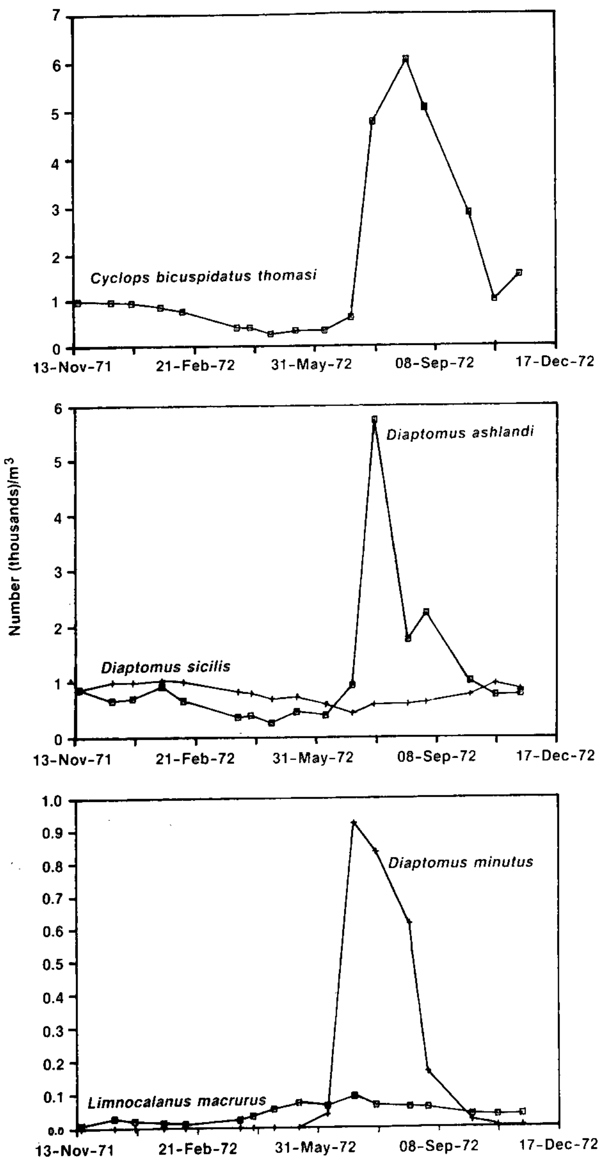


Figure 29. Abundance of copepods in open waters of the St. Marys River, 17 November 1971 to 17 November 1972 (Selgeby 1975).

Benthic Invertebrates

Benthic invertebrates may be separated according to size into macro-, meio-, and microbenthos. Benthic macroinvertebrates are generally considered as those organisms retained by sieves with screen openings of 250-500 µm, meiobenthos are organisms retained by sieves in the 62-250 µm range, and microbenthos those animals passing through sieves with 62 µm openings. In freshwater ecology, relatively little emphasis has been placed on separate size classes of benthic invertebrates, and when finer mesh sieves have been used, the goal has often been to quantify the abundance of early instars of aquatic insects or other macroinvertebrates.

Benthic micro- and meioinvertebrates. The micro- and meiobenthos of the Great Lakes have remained largely unstudied (Nalepa and Quigely 1983) and little quantitative information exists for these components of the St. Marys River benthic community. Liston et al. (1980) list percentages of various benthic invertebrates retained by sieves of 600, 250, and 149 µm aperture (Table 18). Although these data illustrate size distributions of macrobenthic invertebrates and that some are in the size range of meiobenthos, the meiobenthic invertebrates were not specifically examined in this study. Information which does exist for meio- and microbenthos in the St. Marys River suggests nematodes, ostracodes, and Hydra spp. are most abundant (Schirripa 1983; Duffy 1985). Other meiobenthos recorded include cyclopoid and harpactacoid copepods, cladocerans, tardigrades, and Nemertinea (Hiltunen 1979; Poe et al. 1980; Duffy 1985).

Benthic macroinvertebrates. In contrast to the micro- and meiobenthos, there is considerable information on the

Table 18. Percentages of macroinvertebrate taxa from the St. Marys River retained by 600 µm, 250 µm, and 14 µm sieves (Liston et al. 1980).

Taxa	Sieve aperture		
	600 µm	250 µm	149 µm
Oligochaeta	55%	44%	1%
Amphipoda	93	7	--
Isopoda	100	--	--
Ephemeroptera	70	28	2
Trichoptera	97	3	--
Corixidae	100	--	--
Chironomidae	14	70	16
Ceratopogonidae	40	57	3
Hydracarina	48	48	4

distribution and abundance of benthic macroinvertebrates. The earliest published information was records of mollusks collected in the vicinity of Drummond Island and eastern Chippewa County (Goodrich and Van der Schalie 1939). Studies during the 1960's, 70's, and 80's by both American and Canadian researchers produced the bulk of data now available on benthic fauna of the river. Some care must be used in comparing studies, however, since sieves with different size mesh openings have been employed and those studies utilizing finer mesh sieves in the St. Marys River (Liston et al. 1986) and elsewhere have demonstrated shifts in composition and abundance caused by the increased retention of smaller organisms (Nalepa and Robertson 1981).

The St. Marys River supports a diverse benthic invertebrate community; 303 separate taxa have been recorded (Table 19). Benthic invertebrate community composition is influenced primarily by substrate composition, depth, water temperature, water currents, and the presence and density of aquatic macrophytes. For purposes of this monograph, four distinct habitats will be recognized: soft substrates, emergent wetlands, rapids, and the shipping channel. In addition, wave-swept rock shores are a separate habitat for which only qualitative information exists. Two broad taxonomic groups, Chironomidae and Oligochaeta, are numerically abundant in almost all habitats. Other important benthic taxon, such as burrowing mayflies, are restricted to specific habitat types.

Soft substrates occupy the majority of the river's bottom beyond the outer edge of emergent wetlands or rocky shores. At the head of the river, where wave energy from Whitefish Bay is dissipated in shallow water, sediment is predominantly sand interspersed with patches of gravel, cobble, or rock (Figure 30; Duffy et al. 1985). Sediments in the middle and lower river below the rapids are composed of finer particle silts and clays (Figure 30). These silts and clays cover extensive areas of the lower river except where dredged material has been disposed, sandy areas along exposed shorelines, and occasional rock outcrops. In the absence of overriding factors, such as point-source pollution, sediment character has a major influence on benthic community composition and abundance.

Water depth and current act in concert with substrate character in influencing the benthic invertebrate community. Investigations of sandy substrates near the head of the river indicate that maximum densities of benthic macroinvertebrates occur at depths of 11-15 m (Duffy et al. 1985; Figure 31). Results from this study also indicated that fine sand substrates supported greater densities of benthic macroinvertebrates than medium-to-coarse sand. Storms from Lake Superior and Whitefish Bay routinely generate 1.5-2 m waves in the river's headwaters, which hinders macroinvertebrate colonization of loose sand substrates in shallow water.

The lower river has a predominantly silt and clay substrate and is not subject to violent storms; its abundance of benthic invertebrates is relatively uniform among all depths and habitat types, except for the shipping channel (Figure 32). The number of taxa is also negatively correlated with increasing depth in the lower river (Figure 33). These results support the hypothesis of Barton and Griffiths (1984), who suggest that exposure to wind has a significant influence on the Great Lakes benthic community inhabiting depths shallower than 20 m.

Table 19. Macroinvertebrates collected from the St. Marys River (Duffy unpubl. data).

Scientific name
PORIFERA
Eunapius fragilis
Spongilla lacustris
TARDIGRADA
COELENTERATA
Hydra americana
TURBELLARIA
Dugesia sp.
NEMERTEA
BRYOZOA
OLIGOCHAETA
Branchiobdellidae
Bdellodrilus sp.
Glossoscolecidae
Sparganophilus eiseni
Haplotaxidae
Haplotaxis gordioides
Lumbriculidae
Lumbriculus variegatus
Stylodrilus heringianus
Naididae
Amphichaeta sp.
Arctionais lomondi
Chaetogaster diastriphus
Chaetogaster limnae
Nais barbata
Nais communis
Nais simplex
Nais variabilis
Ophidonais serpentina
Paranais littoralis
Paranais simplex
Piquetiella michiganensis
Pristina foreli
Pristina longiseta longiseta
Specaria josinae
Stevensoniana trivandana
Stylaria fossularis
Uncinais uncinata
Vejdovskyella comata
OLIGOCHAETA (Continued)
Tubificidae
Aulodrilus americanus
Aulodrilus limnobius
Aulodrilus piqueti
Aulodrilus pleuriseta
Euilyodrilus vejdovskyi
Limnodrilus angustipenis
Limnodrilus cervix
Limnodrilus cladaredeanus
Limnodrilus hoffmeisteri
Limnodrilus profundicola
Limnodrilus spiralis
Limnodrilus udekemianus
Peloscolex ferox
Peloscolex freyi
Peloscolex multisetosis
Peloscolex superiorensis
Peloscolex variegatus
Potamothrix moldaviensis
Potamothrix vejdovskyi
Psammoryctides curvisetosus
Rhyacodrilus montana
Rhyacodrilus coccineus
Tubifex ignotus
Tubifex kessleri
Tubifex newaensis
Tubifex templetoni
Tubifex tubifex
HIRUDINEA
Erpobdellidea
Dina lateralis
Erpobdella punctata
Mooreobdella microstoma
Nephelopsis obscura
Glossiphoniidae
Actinobdella sp.
Actinobdella inequiannulata
Batracobdella michiganiensis
Glossophonia complanata
Helobdella elongata
Helobdella fusca
Helobdella michiganiensis
Helobdella stagnalis
Placobdella montifera
Hirudinidae
Haemopsis marmata

(Continued)

Table 19. (Continued).

Scientific name	Scientific name
HIRUDINEA (Continued)	EPHEMEROPTERA (Continued)
Macrobdella decora	Caenidae
Pisacolidae	Brachycercus sp.
Pisacola spp.	Caenis sp.
	Ephemeridae
POLYCHAETA	Ephemerella sp.
	Ephemera simulans
Manayunkia speciosa	Hexagenia limbata
	Heptageniidae
ISOPODA	Stenacron sp.
	Stenonema tripunctatum
Asellidae	Leptophlebidae
Asellus intermedia	Leptophlebia sp.
Asellus racovitzae racovitzae	Paraleptophlebia sp.
Lireus sp.	Metretopodidae
	Siphloplecton sp.
AMPHIPODA	Siphlonuridae
	Ameletus sp.
Gammaridae	Isonychia sp.
Allocrangonyx sp.	Parameletus sp.
Crangonyx gracilis	
Gammarus fasciatus	ODONATA
Talitridae	
Hyalella azteca	Aeschnidae
Haustoriidae	Aeschna canadensis
Pontoporeia hoyi	Boyeria sp.
	Coenagrionidae
DECAPODA	Enallagma boreale
	Enallagma hageni
Astacidae	Nehalennia irene
Orconectes propinquus	Cordulidae
Orconectes virilis	Epicordulia
	Somatochlora sp.
ACARINA	Gomphidae
	Arigomphus sp.
Hydracarina	Dromogomphus spinosus
	Lestidae
COLLEMBOLA	Lestes disjunctus
	Libellulidae
Isotomurus sp.	Libelulla sp.
	Sympetrum rubicundilum
EPHEMEROPTERA	
	HEMIPTERA
Baetidae	
Baetis sp.	Belostomatidae
Callibaetis sp.	Belostoma sp.
Cloen sp.	Lethocerus sp.
Baetiscidae	Corixidae
Baetisca sp.	Sigara alternata
	Trichocorixa sp.

(Continued)

Table 19. (Continued).

Scientific name	Scientific name
HEMIPTERA (Continued)	TRICHOPTERA (Continued)
Gelastocoridae	*Trianodes* sp.
Gelastocoris sp.	*Setodes* sp.
Gerridae	Limnephilidae
Gerris sp.	*Grammotaulus* sp.
Hebridae	*Limnephilus* sp.
Hebrus sp.	*Nemotaulus* sp.
Merragata sp.	*Platycentropus* sp.
Hydrometridae	*Pycnopsyche* sp.
Hydrometra sp.	Molannidae
Mesoveliidae	*Molanna* sp.
Mesovelia sp.	Philopotamidae
Nepidae	*Wormaldia* sp.
Ranatra sp.	Phryganeidae
Notonectidae	*Agrypnia* sp.
Buenoa sp.	*Banksiola* sp.
Veliidae	*Fabria* sp.
Microvelia sp.	*Phryganea* sp.
	Ptilostomis sp.
MEGALOPTERA	Polycentropidae
	Phylocentropus sp.
Sialis sp.	*Polycentropus* sp.
	Psychomyiidae
NEUROPTERA	*Psychomia* sp.
	Rhyacophilidae
Sisyra sp.	*Rhyacophila* sp.
TRICHOPTERA	LEPIDOPTERA
Helicopsychidae	Pyralidae
Helicopsyche borealis	*Acentropus* sp.
Hydropsychidae	*Bellura* sp.
Cheumatopsyche sp.	*Nymphula* sp.
Hydropsyche sp.	*Paraponyx* sp.
Potamyia flava	
Hydroptilidae	PLECOPTERA
Hydroptila sp.	
Ithytrichia sp.	Perlidae
Ochrotrichia sp.	*Isoperla* sp.
Oxyethira sp.	
Lepidostomatidae	COLEOPTERA
Lepidostoma sp.	
Leptoceridae	Chrysomelidae
Ceraclea sp.	*Donacia* sp.
Mystacides sp.	Dytiscidae
Nectopsyche sp.	*Deronectes depressus*
Neuroclipsis sp.	*Hydrovatus* sp.
Nyctiophylax sp.	Elmidae
Oecetis sp.	*Dubiraphia* sp.

(Continued)

Table 19. (Continued).

Scientific name	Scientific name
COLEOPTERA (Continued)	DIPTERA (Continued)
Microcylleopus sp.	Heterotrissocladius sp.
Gyrinidae	Labrundinia sp.
Gyrinus sp.	Larsia sp.
Dineutus sp.	Lauterborniella sp.
Haliplidae	Metriocnemus sp.
Brychius sp.	Microspectra sp.
Haliplus sp.	Microtendipes sp.
Haliplus cribrarius	Monodiamesa sp.
Hydrophilidae	Orthocladus sp.
Helophorus sp.	Parachironomus sp.
Noteridae	Paracladopelma sp.
Hydrocanthus sp.	Paralauterborniella sp.
Pronoterus sp.	Parametriocnemus sp.
Psephenidae	Paratanytarsus sp.
Psephenus sp.	Phaenospectra sp.
	Polypedilum sp.
HYMENOPTERA	Potthastia sp.
	Procladius sp.
DIPTERA	Psectrocladius sp.
	Psectrotanypus sp.
Anthomyiidae	Pseudochironomus sp.
Ceratopogonidae	Pseudosmittia sp.
Alludomyia needhami	Rheotanytarsus sp.
Bezzia varicolor	Stempellinia sp.
Culicoides sp.	Stenochironomus sp.
Dasyhelia sp.	Stictochironomus sp.
Palpomyia prunescens	Tanytarsus sp.
Stilobezzia sp.	Thienemanniella sp.
Chironomidae	Tribelos sp.
Ablabesmia sp.	Trissocladius sp.
Chironomus sp.	Xenochironomus sp.
Cladotanytarsus sp.	Culicidae
Clinotanypus sp.	Aedes intrudens
Coleotanypus sp.	Chaoborus sp.
Conchapelopia sp.	Dixidae
Constempellina sp.	Dixa sp.
Corynoneura sp.	Ephydridae
Cricotopus sp.	Empididae
Cryptochironomus sp.	Hemerodromia sp.
Cryptocladopelma sp.	Sciomyzidae
Cryptotendipes sp.	Sepedon fuscipenis
Demicryptochironomus sp.	Simulidae
Diamesa sp.	Simulium sp.
Dicrotendipes sp.	Stratiomyiidae
Endochironomus sp.	Stratiomys sp.
Enfeldia sp.	Tabanidae
Epocicocladius sp.	Chrysops sp.
Eukerferrilia sp.	Tipulidae
Glyptotendipes sp.	Antocha sp.

(Continued)

Table 19. (Concluded).

Scientific name	Scientific name
DIPTERA (Continued)	GASTROPODA (Continued)
Erioptera sp.	*Promenetus exacuous exacuous*
	Planorbula armiger
GASTROPODA	Pleuroceridae
	Goniobasis livescens
Ancylidae	*Pleurocera acuta*
Ferrisia paralella	Truncatellidae
Hydrobiidae	*Pomatiopsis lapidaria*
Amnicola limnosa	Valvatidae
Amnicola walkeri	*Valvata sincera sincera*
Probythinella lacustris	*Valvata tricaranata*
Somatogyrus subglobosus	Viviparidae
Lymnaeidae	*Campeloma decisum*
Acella haldemani	
Aplexa hypnorum	PELECYPODA
Bulimnea megasoma	
Fossaria parva	Unionidae
Lymnaea palustris	*Alasmidonta calceolus*
Lymnaea stagnalis	*Anodonta grandis grandis*
Lymnaea stagnalis jugularis	*Anodontoides ferussacianus*
Lymnaea stagnalis sanctae mariae	*Elliptio complanata*
Pseudosuccinus columella	*Lampsilis radiata siliquoidea*
Stagnicola catascopium catascopium	*Lasmigona compressa*
	Lasmigona costata
Stagnicola elodes	*Ligumia recta latissima*
Physidae	Sphaeriidae
Physa gyrina gyrina	*Pisidium compressum*
Physa heterostropha	*Pisidium fallax*
Physa integra	*Pisidium nitidum*
Physa jennessi skinneri	*Pisidium idahoensis*
Planorbidae	*Pisidium variabile*
Helisoma anceps anceps	*Pisidium* sp.
Helisoma campanulatum	*Sphaerium nitidum*
Helisoma corpulentum vermilion	*Sphaerium occidentale*
Helisoma trivolvis trivolvis	*Sphaerium rhomboideum*
Helisoma trivolvis binneyi	*Sphaerium securis*
Gyraulus deflectus	*Sphaerium striatinum*
Gyraulus parvus	*Sphaerium* sp.

The benthic invertebrate community of soft substrates in the St. Marys River may be characterized as one dominated both numerically and in terms of taxonomic diversity by chironomid larvae and oligochaetes. Fifty-one separate taxa

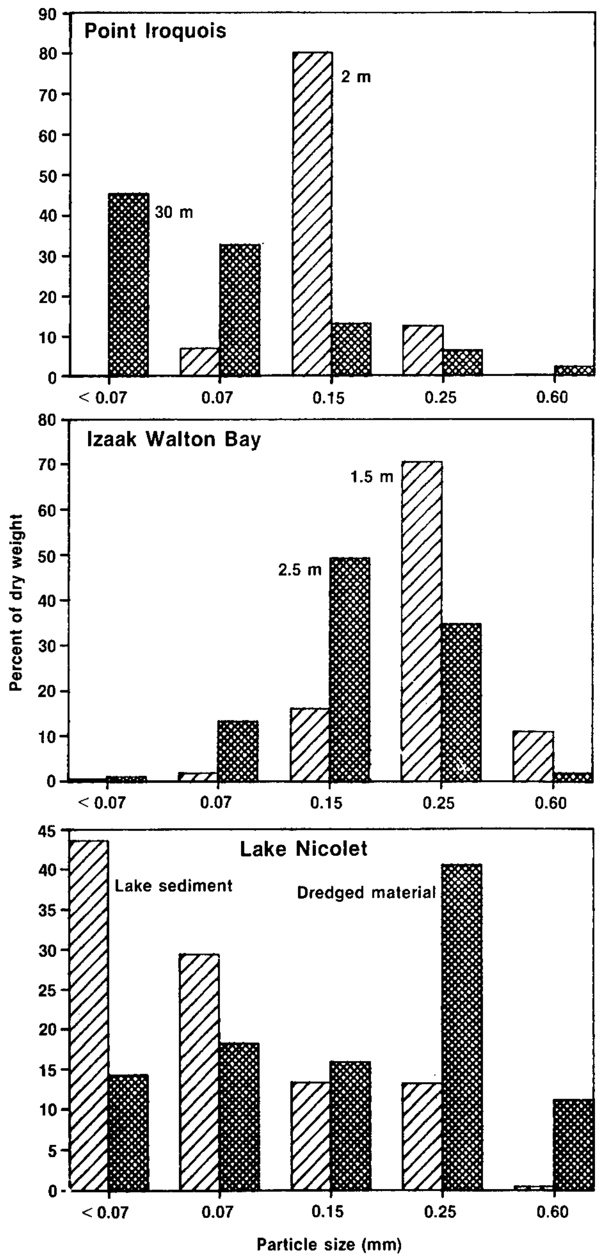


Figure 30. Sediment particle size distribution downstream of Point Iroquois and Izaak Walton Bay in the upper portion and in Lake Nicolet in the lower portion of the St. Marys River.

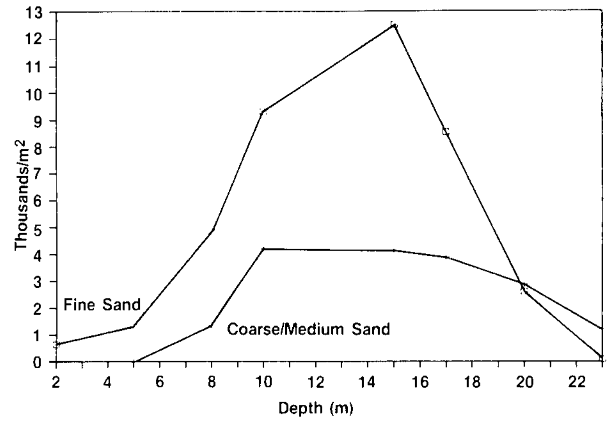


Figure 31. Distribution of total benthos in fine sand and coarse/medium sand by depth in the St. Marys River.

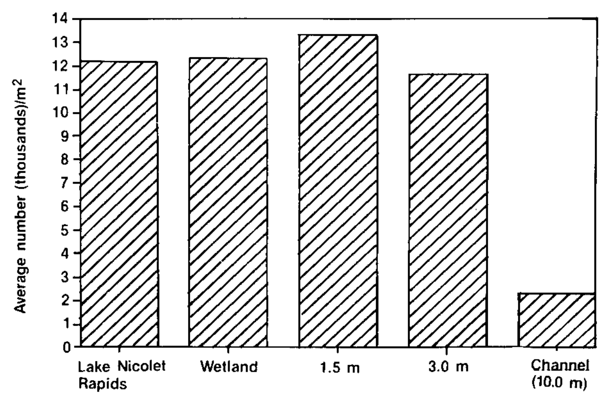


Figure 32. Abundance of total benthos by depth and habitat in the lower St. Marys River during 1982 and 1983.

each of chironomids and oligochaetes have been recorded from the river. Studies using finer mesh sieves (Liston et al. 1980, 1983, 1986), compared to studies using coarser mesh sieves (Hiltunen 1979; Poe and Edsall 1982), generally report chironomids as being more abundant than oligochaetes. Data collected from the same areas by Hiltunen (1979) and Liston et al. (1986) indicate chironomids are underrepresented in samples rinsed through coarse mesh (500 μ) sieves, while oligochaetes are apparently not (Figure 34).

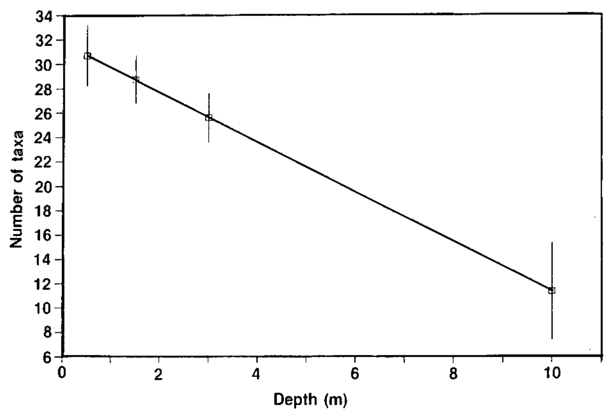


Figure 33. Relationship between diversity of benthic invertebrates and water depth in the lower St. Marys River.

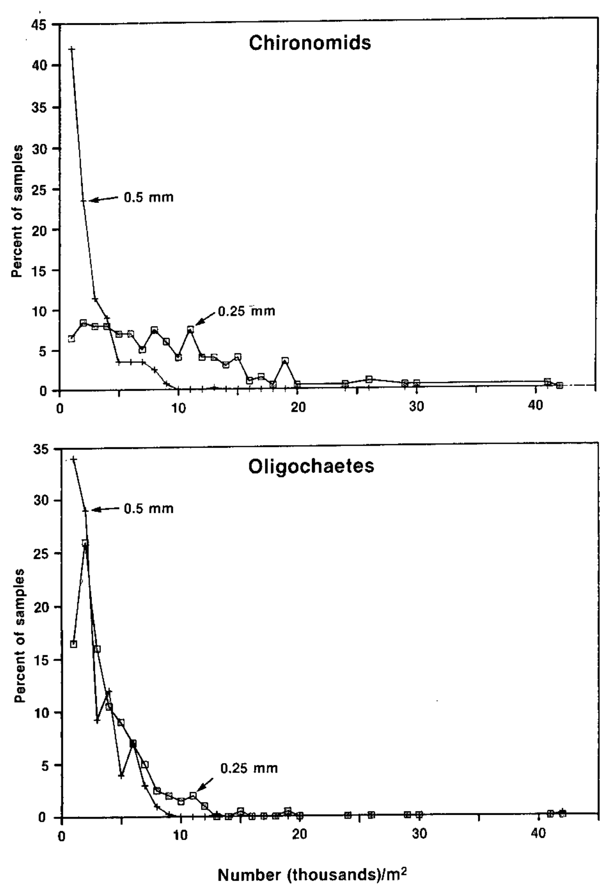


Figure 34. Comparison of estimated abundance of chironomids and oligochaetes in the St. Marys during 1982, taken using two separate seive sizes (Hiltunen 1979; Liston et al. 1986).

Three genera of chironomids, Larsia spp., Procladius spp., and Stichtochironomus spp., are ubiquitous and another 10 genera are common in one or more parts of the river (Table 20). Chironomids represent the greatest proportion of the total benthic community in sand substrate near the head of the river, but they are most abundant numerically in the middle reaches of the river (Table 21). In contrast to the chironomids, oligochaetes generally represent a progressively larger proportion of the total benthic fauna as one proceeds from the upper to lower river (Table 21). However, organic enrichment in the upper river near Sault Ste. Marie has stimulated the population explosion of certain pollution-tolerant species of oligochaetes (see below).

The soft bottom benthic invertebrate community consists of a variety of other taxa. While Chironomidae and Oligochaeta are most diverse and abundant, other taxa, such as Ephemeroptera, Amphipoda, and Mollusca, are common or abundant and contribute substantially to standing stock biomass (Table 21). Because of their central role in trophic interactions, Ephemeroptera may be the most important group of benthic invertebrates in the St. Marys River. Eighteen species or genera have been collected from the river. Nymphs of two may-fly species, Hexagenia limbata and Ephemera simulans, are particularly abundant in areas of soft substrate. Nymphs of both species grow quite large relative to most aquatic invertebrates and, with the more abundant H. limbata having a 2-year life cycle in the St. Marys River, can represent a considerable proportion of the standing stock biomass (Liston et al. 1983; Schloesser and Hiltunen 1985). Throughout its range, H. limbata is most abundant in depositional environments where fine sediments predominate, while species of Ephemera are reported to prefer substrates of slightly coarser sediments (Hunt 1953; Erickson 1968). The distribution of both mayflies in the St. Marys River generally supports these observations. Hexagenia limbata is most abundant in parts of Lakes George and Nicolet and in the lower river where fine sediments occur, while E. simulans is more common in coarser sediments of Lake Nicolet and the upper river (Hiltunen 1979; Liston 1983,

Table 20. Benthic macroinvertebrates characteristic (occur at >50% of stations) of separate reaches of the St. Marys River (Duffy unpubl. data).

Taxa	River Reach			
	Upper	Middle	Lower	Lake George
Oligochaeta				
Limnodrilus hoffmeisteri	X		X	
Limnodrilus sp.		X	X	
Peloscolex ferox	X			X
Peloscolex sp.			X	
Potamothrix vejdovski		X		
Amphichaeta sp.		X		
Ophidonais serpentina		X		
Isopoda				
Asellus sp.		X		
Amphipoda				
Gammerus fasciatus			X	X
Hyalella azteca		X	X	X
Acarina				
Hydracarina	X	X	X	X
Ephemeroptera				
Ephemera simulans		X		
Hexagenia limbata		X	X	X
Trichoptera				
Mystacides sp.		X		
Phylocentropus sp.				X
Polycentropus sp.		X		X
Diptera (Chironomidae)				
Ablabesmia sp.		X		X
Cricotopus sp.	X			
Cryptochironomus sp.	X	X	X	
Dicrotendipes sp.		X		X
Endochironomus sp.	X			
Larsia sp.	X	X	X	X
Paratanytarsus sp.	X	X		
Polypedilum sp.		X	X	X
Procladius	X	X	X	X
Psectrocladius sp.			X	X
Stictochironomus sp.	X	X	X	X
Tanytarsus sp.			X	
Thienemanniella sp.	X			
Mollusca				
Amnicola sp.		X	X	X
Physa sp.		X		
Pisidium idahoensis	X			X
Pisidium sp.		X	X	
Sphaerium sp.		X		

Table 21. Average number of benthic macroinvertebrates/m² and percent of the total represented by major taxonomic groups collected from offshore stations of the St. Marys River during 1983 (Duffy unpubl. data).

Taxa	Location[a] IWB	LN	MNC	NML	SML	PAF	RB
Average number/m²	9,879	18,710	20,846	13,895	8,613	9,682	7,381
				Percent			
Oligochaeta	14	17	21	21	29	41	35
Polychaeta	0	7	<1	2	2	1	4
Amphipoda	2	5	2	<1	5	3	2
Isopoda	<1	3	2	1	1	<1	0
Ceratopogonidae	3	1	3	2	5	1	0
Chironomidae	73	64	67	67	52	44	48
Ephemeroptera	3	3	3	2	6	6	6
Trichoptera	<1	<1	<1	<1	<1	<1	<1
Gastropoda	1	1	<1	2	2	<1	<1
Pelecypoda	1	<1	<1	<1	1	2	2
Other	3	<1	1	2	2	2	1

[a]Initials correspond to the following areas of the river: IWB = Izaac Walton Bay, LN = Lake Nicolet, MNC = Middle Neebish Channel, NML = north Munuscong Lake, SML = south Munuscong Lake, PAF = Pt. aux Frenes, and RB = Raber Bay.

1986). Trichoptera are almost never numerically abundant, but are one of the most taxonomically diverse benthic groups in the St. Marys River.

The distribution of benthic macroinvertebrates of soft substrates was surveyed by Veal (1968) in relation to industrial and municipal discharges from the city of Sault Ste. Marie, Ontario. Veal found that sediments below these effluents contained elevated levels of chromium, iron oxide, phenols, phosphorus, and nitrogen. Wood chips and oil were also present in some areas. Within this zone of contaminated sediments the mayfly Hexagenia occurred only occasionally and the typical soft bottom benthic fauna of the river was replaced by one consisting, entirely in some areas, of the pollution-tolerant oligochaetes Tubifex tubifex and Limnodrilus hoffmeisteri. At the time of Veal's (1968) sampling, these impacts to the benthic community extended from an area immediately above the rapids to Little Lake George at the northeast corner of Sugar Island (Figures 35, 36). Veal (1968) suggested that the American side of the river and Lake Nicolet were not contaminated by industrial discharges. However, sampling intensity in these areas may not have been great enough to determine if the benthic community had been altered. Since this survey, the area has again been sampled by Hamdy et al. (1978) and Kenega (1979), both of whom generally corroborate Veal's earlier work. A later survey of the distribution of Hexagenia by Hiltunen and Schloesser (1983) indicated these mayflies had been eliminated from areas slightly further downstream than previously suggested. Hiltunen and Schloesser (1983) correlated the absence of Hexagenia with the presence of oil in sediments. Oil would severely reduce osmoregulatory and feeding efficiency as well as general movements of Hexagenia nymphs. Hiltunen and Schloesser (1983) also report observing emerging subimagoes entrapped in surface oil film.

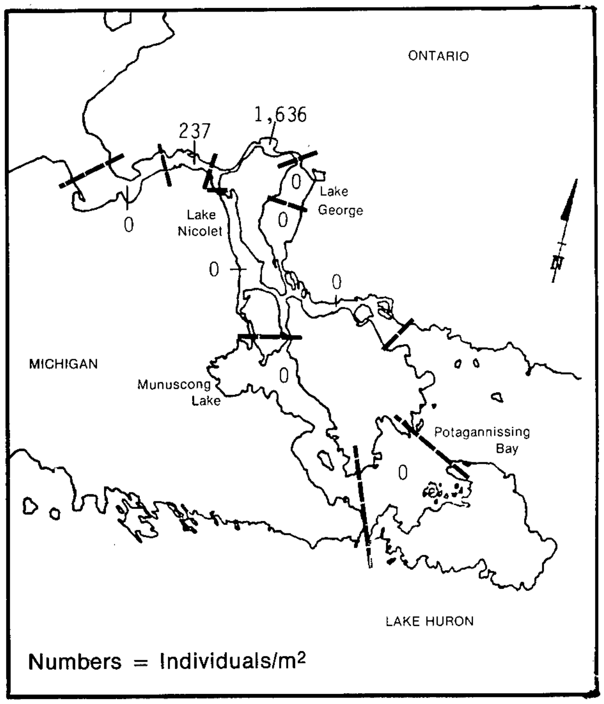


Figure 35. Distribution of Tubifex tubifex in the St. Marys River.

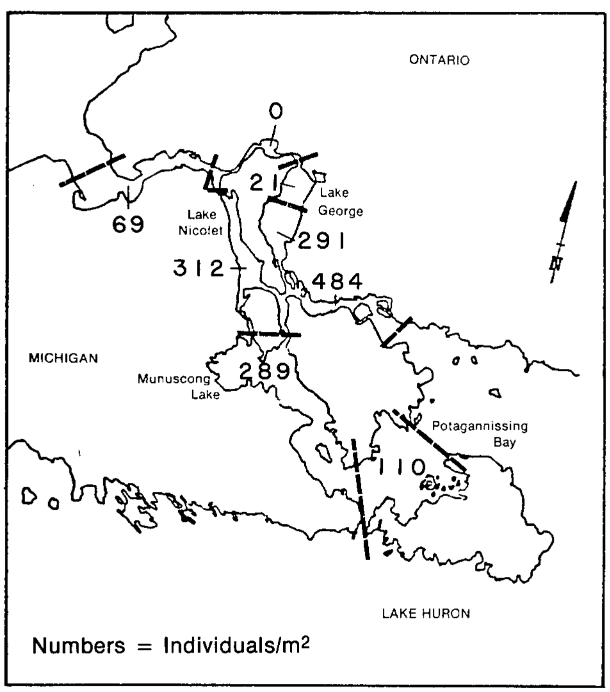


Figure 36. Distribution of Hexagenia spp. in the St. Marys River.

Except for this area of sediment and water-quality impairment, the soft bottom benthic fauna of the river is indicative of good water quality. Common oligochaetes found throughout the river are a mixture of pollution-tolerant taxa (Limnodrilus hoffmeisteri and Limnodrilus spp.) and species associated with mesotrophic conditions (Peloscolex ferox and Potamothrix vejdovski; Table 20). Species intolerant of organic enrichment, such as Stylodrilus heringianus, are also found over wide areas of the river (Veal 1968; Hiltunen 1979; Liston et al. 1980). However, oligochaetes generally are not present in high densities outside of the zone of organic enrichment around Sault Ste. Marie. Chironomids associated with clean water, such as Heterotrissocladius spp., Microspectra spp., and Polypedilum spp., are common, while the pollution-tolerant Chironomus spp. are rare.

The shipping channel is essentially a portion of the soft-bottom habitat which has been altered by dredging. This area is apparently poor habitat for benthic macroinvertebrates as only two taxa are common and both diversity and density are much lower in the shipping channel than in all other habitats (Table 22; Liston et al. 1980, 1986). The sole exception is in areas where depositional material settles within the channel. This occurs at the junction of the Middle Neebish Channel and Munuscong Lake and in the southern portion of the river below Munuscong Lake. Here, the polychaete worm Manyunkia speciosa and oligochaetes sometimes reach abundance. Turbulence created by passing ships and their propwash is likely the reason for the lack of benthic organisms in the shipping channel.

Emergent wetlands provide a habitat for benthic macroinvertebrates that is alternately benign and harsh. In winter, ice may extend through the water column into bottom sediments in many of the emergent wetlands of the St. Marys River. Still, some aquatic invertebrates remain in these areas throughout winter and convert blood sugars into alcohols in order to prevent freezing (Duffy and Liston 1985). However, in spring, water temperatures rise more rapidly in these shallow areas than do water temperatures offshore, allowing growth to begin earlier (see Chapter 2).

Table 22. Average number of benthic macroinvertebrates/m² and percent of the total represented by major taxonomic groups collected from shipping channel stations of the St. Marys River during 1983 (Duffy unpubl. data).

Taxa	Location[a]						
	IWB	LN	MNC	NML	SML	PAF	RB
Average number/m^2	854	597	647	4,403	455	693	1,841
	Percent						
Oligochaeta	6	45	7	36	23	43	24
Polychaeta	0	0	0	14	0	0	52
Amphipoda	<1	2	0	<1	2	0	0
Isopoda	0	0	<1	<1	0	0	0
Ephemeroptera	0	6	0	7	0	1	<1
Trichoptera	0	0	0	<1	<1	0	0
Ceratopogonidae	0	0	11	3	0	0	0
Chironomidae	93	41	72	38	67	56	23
Gastropoda	0	0	<1	0	2	0	0
Pelecypoda	0	0	0	<1	<1	0	<1
Other	<1	6	10	2	4	0	<1

[a]For key to area of river abbreviations see Table 21.

Water temperatures in these shallow areas also reach greater maximum levels in summer than in offshore sites, again favoring development. The structure provided by aquatic macrophytes serves as substrate for periphytic growth, which many of the invertebrates feed on, and as cover from fish and other predators. Emery (1978) characterized aquatic macrophyte beds and wetlands as "organic matrices" which favor diversity in aquatic ecosystems much as coral reefs in marine environments do.

The benthic macroinvertebrate community of emergent wetlands in the St. Marys River, like the soft-bottom community, is taxonomically diverse. A total of 171 separate taxa have been recorded from emergent wetlands, with 118 of these being aquatic insects. Among the insects, Chironomidae represent the richest fauna of emergent wetlands with 38 genera, while other groups poorly represented in the soft-bottom community, such as Hemiptera, Odonata, and Coleoptera, are well represented in emergent wetlands (Table 20).

The abundance of benthic invertebrates in wetlands appears to be influenced by the degree of wind exposure. This influence is from the direct physical effects of wave action that Barton and Hynes (1981) describe for other parts of the Great Lakes, from the negative effects of wind on macrophyte development, and the effects of wind on macrophyte community composition. Comparison of benthic invertebrate densities reported from both lee and windward wetlands of the lower river reveals that densities in wetlands exposed to wind (Table 23) are almost consistently lower than densities found in wetlands on the lee side (Table 24). Whereas Liston and his colleagues (1986) sampled primarily *Scirpus acutus* stands, Duffy (1985) studied the invertebrate community inhabiting *Sparganium eurycarpum* stands. The invertebrate community associated with *S. eurycarpum*, which tends to occur in more protected areas, was more diverse than the invertebrate community associated with *Scirpus acutus*, with Hemiptera, Odonata, Coleoptera, and Hirudinea each common at times (Table 25).

Chironomids and oligochaetes numerically dominate the emergent wetland

Table 23. Average number of benthic macroinvertebrates/m² and percent of the total represented by major taxonomic groups collected from windward emergent wetland stations of the St. Marys River during 1983 (Duffy unpubl. data).

Taxa	Location[a]			
	NML	SML	PAF	RB
Average number/m²	2,735	7,070	10,967	8,382
	Percent			
Oligochaeta	17	20	70	36
Polychaeta	<1	42	<1	2
Amphipoda	1	<1	2	2
Isopoda	<1	0	<1	<1
Ephemeroptera	<1	3	1	<1
Trichoptera	<1	<1	<1	<1
Ceratopogonidae	4	<1	<1	<1
Chironomidae	66	32	21	58
Gastropoda	<1	<1	<1	<1
Pelecypoda	<1	<1	<1	<1
Other	6	<1	3	<1

[a]For key to area of river abbreviations see Table 21.

Table 24. Average number of benthic macroinvertebrates/m² and percent of the total represented by major taxonomic groups collected from lee emergent wetland stations of the St. Marys River during 1983 (Duffy unpubl. data).

Taxa	Location[a]						
	IWB	LN	MNC	NML	SML	PAF	RB
Average number/m²	9,391	15,692	10,260	7,642	18,607	10,638	19,267
	Percent						
Oligochaeta	24	15	14	26	65	80	66
Polychaeta	0	<1	3	<1	18	1	2
Amphipoda	1	1	2	4	<1	<1	1
Isopoda	0	2	<1	4	<1	0	<1
Ephemeroptera	3	5	<1	1	<1	<1	<1
Trichoptera	<1	2	<1	<1	<1	0	<1
Ceratopogonidae	5	<1	3	<1	<1	0	<1
Chironomidae	64	72	79	58	15	18	22
Gastropoda	<1	1	<1	<1	<1	0	<1
Pelecypoda	<1	1	<1	<1	<1	<1	<1
Other	1	<1	<1	4	<1	<1	7

[a]For key to area of river abbreviations see Table 21.

Table 25. Average number of benthic macroinvertebrates/m² and percent of the total represented by major taxonomic groups in Sparganium eurycarpum stands in the St. Marys River during 1983 (Duffy 1985).

Taxa	Date 13 May	17 June	6 July
	Percent		
Oligochaeta	12	47	18
Hirudinea	0	3	2
Amphipoda	4	3	1
Isopoda	0	3	<1
Ephemeroptera	<1	7	2
Odonata	5	1	3
Trichoptera	6	4	<1
Hemiptera	<1	3	<1
Ceratopogonidae	2	<1	5
Chironomidae	67	16	64
Coleoptera	0	1	<1
Gastropoda	4	<1	1
Total number/m²	2,135	10,245	24,043

benthic macroinvertebrate community, just as they do in soft-bottom habitats (Tables 24, 25). Liston et al. (1986) found chironomids were most abundant in the lee wetlands of the Lake Nicolet and middle channel portions of the river. As they did in soft-bottom habitats, oligochaetes represented a greater proportion of the total fauna in the southern portion of the river than in the middle or upper river. Seasonally, maximum densities of oligochaetes were found in June, roughly 1 month prior to peak densities of chironomids (Duffy 1985). However, earlier studies suggested both groups may reach maximum densities later in summer during some years (Duffy unpubl. data).

While chironomids and oligochaetes are the most abundant macroinvertebrates in emergent wetlands, a variety of more conspicuous taxa better serve to characterize this habitat. Characteristic macroinvertebrates of the St. Marys River emergent wetlands include a number of taxa which, having specific habitat requirements, are dependent on and occur only or primarily in this habitat (Table 26). For example, larvae of the beetle Donacia sp. are phytophagus and develop within the stems of the emergent macrophyte Sparganium eurycarpum. While less common, larvae of the moth Bellura spp. have similar habitat requirements, but develop in Scirpus spp. stems. The mayfly Siphloplecton spp. occurs along the wetland face. It is an active swimmer about which little is known since it is infrequently captured by conventional benthic sampling techniques. Many of the Hemiptera and certain species of Odonata are restricted to more dense stands of macrophytes (Duffy 1985).

The great volume of flow combined with the irregular boulder substrate in the St. Marys Rapids has prevented quantitative sampling to date, even though these rapids are considered one of the most important fish habitats in the river. However, information on the benthic macroinvertebrate community inhabiting the rapids was gathered in November 1983 when the International Lake Superior Board of Control (ILSBC) closed the compensating gates at the head of the rapids and "dewatered" the rapids (ILSBC 1974; Koshinsky and Edwards 1983). This enabled biologists to enter the rapids area and examine its benthic fauna. Another approach to understanding the benthic community of the rapids was attempted by Schirripa (1983) who sampled benthic macroinvertebrates in the smaller rapids emptying from Lake Nicolet.

The composition of the benthic macroinvertebrate community of both the St. Marys Rapids and Lake Nicolet Rapids is substantially different from the composition in other habitats in the river (Table 27). In both rapids Trichoptera larvae (especially two genera of net-spinning caddisflies of the family Hydropsychidae, Hydropsyche cf. bifida and Cheumatopsyche spp.) are much more abundant than in other habitats. In the St. Marys Rapids, H. cf. bifida is the predominant taxa, comprising about 80% of the Hydropsychidae (Figure 37). However, in the Lake Nicolet Rapids, Cheumatopsyche spp. are predominant and comprise 95% of the Hydropsychidae (Schirripa 1983). Koshinsky and Edwards (1983) attributed the preponderance of H. cf. bifida in the St. Marys Rapids to its affinity for faster flowing water. Cheumatopsyche spp. are known to

Table 26. Benthic macroinvertebrates characteristic (occur at >50% of stations) of separate habitats in the St. Marys River (Duffy unpubl. data).

Taxa	Habitat: Wetland	Soft bottom	Channel	Rapids
Oligochaeta				
Ophidonais serpentina		x		
Limnodrilus sp.		x		
Peloscolex ferox		x		
Stylaria fossularis	x			
Polychaeta				
Manayunkia speciosa	x			
Amphipoda				
Gammarus fasciatus	x			
Hyalella azteca	x	x		
Hydracarina	x	x	x	x
Ephemeroptera				
Baetis sp.	x			
Caenis sp.	x			
Ephemera simulans	x			
Hexagenia limbata		x		
Stenonema tripunctatum				x
Leptophlebia sp.				x
Trichoptera				
Cheumatopsyche sp.				x
Helicopsyche borealis				x
Hydropsyche bifida				x
Polycentropus sp.	x			
Hemiptera				
Corixidae	x			
Coleoptera				
Donacia sp.	x			
Diptera				
Ceratopogonidae	x	x		
Cryptochironomus sp.	x	x		
Dicrotendipes sp.		x		
Epoicocladius sp.		x		
Larsia sp.	x	x	x	x
Paratanytarsus sp.	x	x		
Polypedilum sp.	x	x		
Procladius sp.	x	x		
Psectrocladius sp.	x			
Stictochironomus sp.	x	x		
Tanytarsus sp.	x	x		
Simulium sp.				x
Mollusca				
Amnicola sp.	x	x		
Physa sp.		x		
Pisidium sp.	x	x		
Sphaerium sp.		x		

Table 27. Average number of common macroinvertebrates/m^2 in the St. Marys Rapids and Lake Nicolet Rapids (Koshinsky and Edwards 1983; Schirripa 1983).

Taxa	Rapids area: Lake Nicolet	Rapids area: St. Marys
Oligochaeta	788	--
Amphipoda	69	rare
Heptageniidae	223	12
Leptophlebia sp.	887	--
Total Ephemeroptera	1,504	--
Hydropsychidae	885	4,660
Total Trichoptera	1,140	--
Chironomidae	8,433	--
Mollusca	13	--
Other	148	--
Total macroinvertebrates	12,096	--
Hydra americana	18,131	--

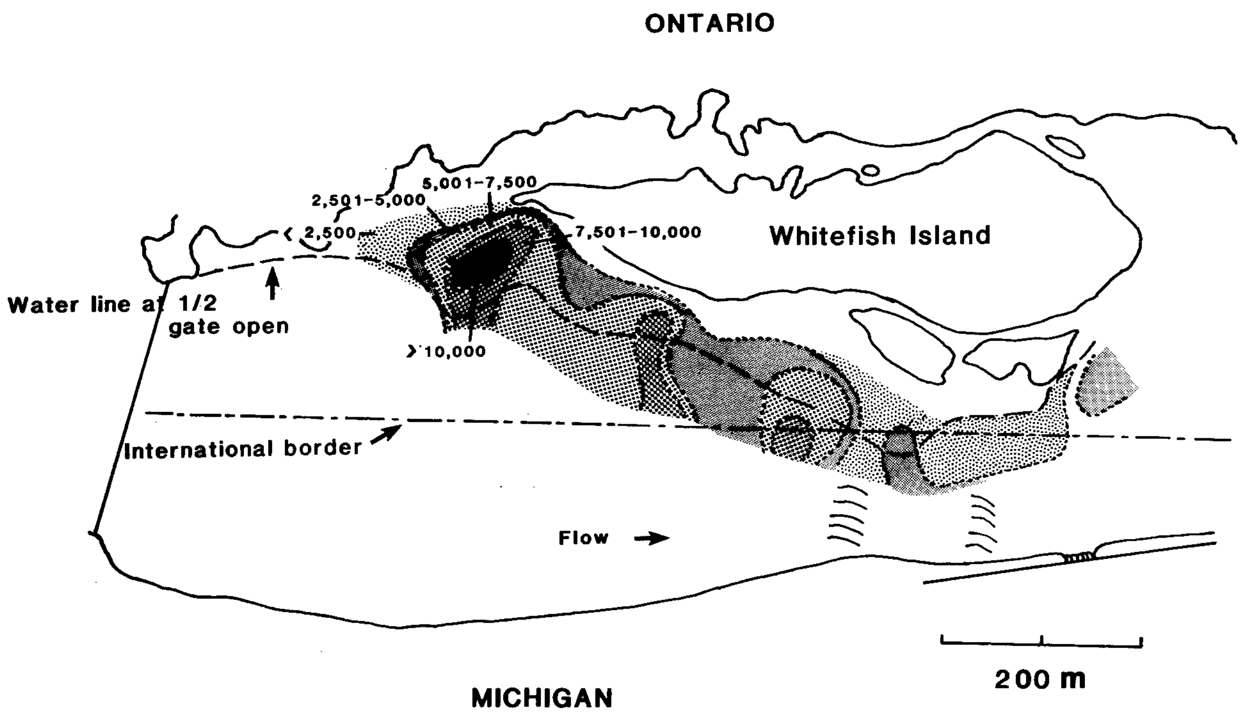


Figure 37. Distribution and abundance of net-spinning caddisfly larvae in dewatered area, St. Marys Rapids, 6-7 November 1973 (Koshinsky and Edwards 1983).

inhabit slower flowing and warmer water than Hydropsyche spp. (Wiggins 1979); these observations seem consistent with the distribution of these taxa in the St. Marys River.

Overall, the macroinvertebrates of both rapids are typical of the benthic communities found in rapids or rocky streams. Differences among the two sites appear to be related primarily to current velocity. In addition to Cheumatopsyche spp., both heptageniid mayflies and the crayfish Orconectes propinquus were more abundant in the moderate flow of the Lake Nicolet Rapids than in the St. Marys Rapids. Schirripa (1983) also found high densities of the meiobenthic Hydra americanus at the Lake Nicolet Rapids during July.

Annual Production of Invertebrates

Production refers to the net productivity or sum of growth increments of all individuals in a population. It includes biomass devoted to eggs and shed exuviae, but excludes energy devoted to maintenance activities (Wetzel 1983). Production gives an indication of how energy flows through an ecosystem and is also of value in comparing ecosystems.

No published information exists for zooplankton production in the St. Marys River. However, Selgeby (1975) reported standing stock biomass of zooplankton entering the river from Whitefish Bay from which inferences about production can be made, and Duffy (unpubl. data) estimated production of zooplankton in emergent wetlands.

In lake water entering the river, zooplankton standing stock increased from roughly 4 mg dry wt/m^3 in early June to 14 mg dry wt/m^3 by late August during a period when average biomass of individual zooplankters was declining (Figure 38). This period of increasing biomass is undoubtedly the period of peak zooplankton production in the open waters of the St. Marys River. The increase in standing stock corresponds with seasonal maximum water temperatures and a pulse in phytoplankton availability.

Zooplankton standing stock in emergent wetlands averaged 3.3 mg dry wt/m^3 during

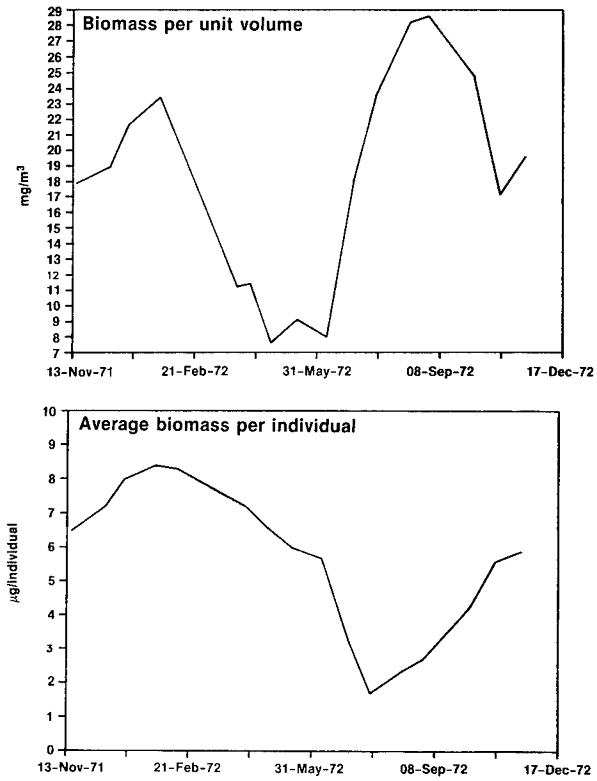


Figure 38. Density of total zooplankton within the Dunbar emergent wetland during 1983 and density and biomass of the open-water area during 1971 and 1972 (Selgeby 1975).

April through July, 1983 (Duffy, unpubl. data). Eurycercus lamellatus and Simocephalus serrulatus, two large cladocerans, contributed most to the estimated annual zooplankton production in the wetlands (Table 28). Seasonally, standing stock values were greatest during late June through early July corresponding with increasing water temperatures, the beginning of the phytoplankton pulse in the river, and a pulse in the release of dissolved organic material from the emergent macrophytes in the wetlands.

Seasonal standing crop of benthic invertebrates reflects trends in abundance, but also size of individuals in the population. However, because of the taxonomic diversity of the benthos, generation times are variable and total standing stock data are not always useful for predicting annual production. For example, with the exception of a peak in

Table 28. Estimated annual secondary production by zooplankton in emergent wetlands of Lake Nicolet of the St. Marys River (Duffy unpubl. data).

Taxa	Production (mg dry wt $\cdot$ m^{-2} $\cdot$ yr^{-1})
Cladocera	
Eurycercus lamellatus	261.7
Simocephalus serrulatus	270.1
Chydorus sphaericus	9.2
Acroperus harpae	2.2
Other Cladocera	17.1
Copepoda	
Macrocyclops albidis	4.3

abundance at the 3 m depth of Lake George during June, benthic invertebrate abundances in both emergent wetlands and soft-bottom areas of Lakes George and Nicolet show similar seasonal trends (Figure 39A, B). Yet, biomass in soft-bottom areas of Lake Nicolet are much lower than in Lake George (Figure 39C, D). These differences are a reflection of differences in species composition between the two basins. The soft bottom areas of Lake George support greater numbers of Hexagenia limbata and fingernail clams (Sphaeriidae) than similar substrates in Lake Nicolet, which support a more abundant chironomid community. However, differences in taxonomic composition and standing stock are not reflected in annual production.

Annual benthic invertebrate production estimates for areas of the St. Marys River

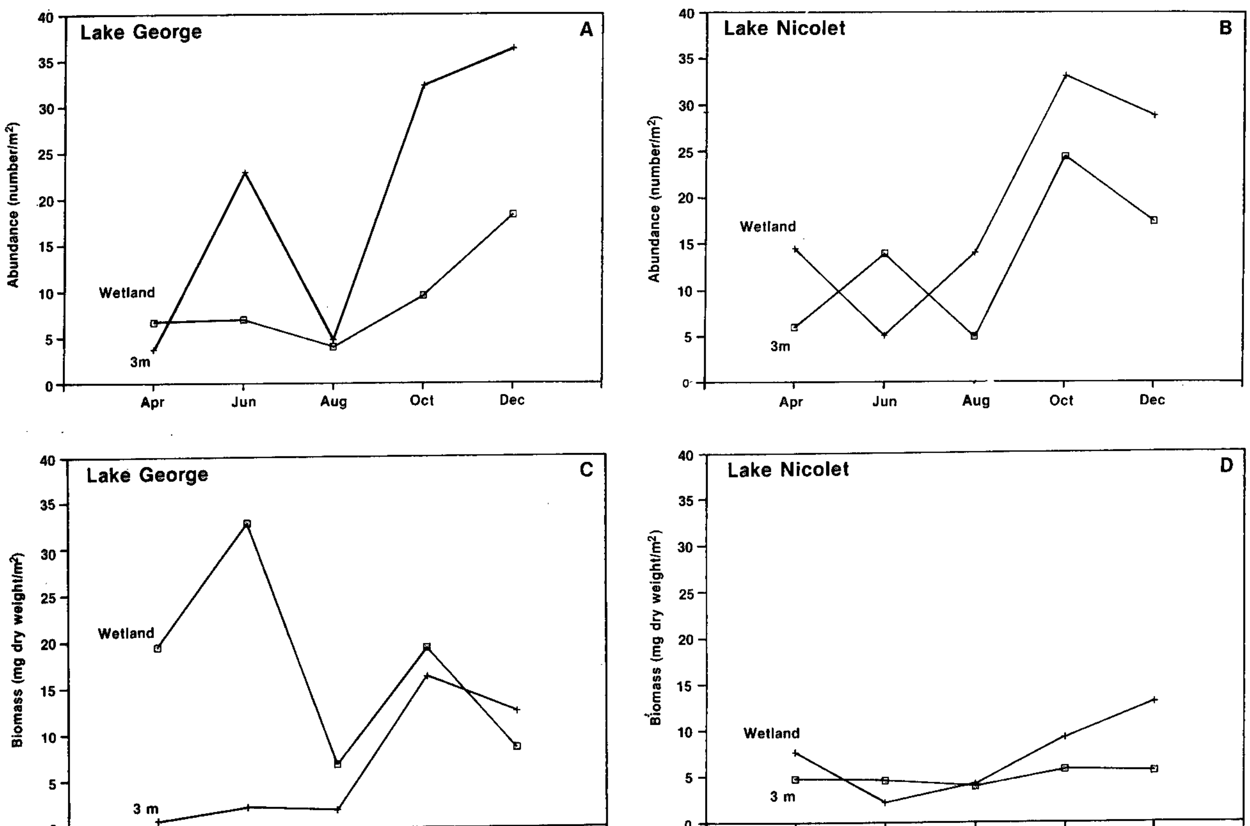


Figure 39. Seasonal abundance and biomass of benthic invertebrates in an emergent wetland of Lake George and the Lake Nicolet emergent wetland of the St. Marys River during 1981.

that have been studied are remarkably similar (Liston et al. 1983; Schirripa 1983; Duffy 1985). In soft bottom offshore areas of Lake George *Hexagenia limbata* and fingernail clams contribute over half of the annual production, while in Lake Nicolet most of the total production is contributed by chironomids, oligochaetes, and the amphipod *Hyallela azteca* (Table 29). Overall, on a unit basis, annual benthic invertebrate production is greater in emergent wetlands and rapids areas than in soft-bottom areas of the river.

Fishes

Juvenile and adult fishes. The fish community of the St. Marys River may be described as a percid community (*sensu* Ryder and Kerr 1978). A percid community contains four critical species which contribute to the persistance of the community: walleye (*Stizostedion vitreum vitreum*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), and white sucker (*Catostomus commersoni*). Kitchell et al. (1977) observed that slow-flowing rivers having a variety of substrates,

Table 29. Estimated benthic invertebrate production in the emergent littoral zone and the 3-m depth contour of Lakes George and Nicolet and in the Lake Nicolet Rapids as mg dry wt · m^{-2} · yr^{-1} (Duffy unpubl. data).

Taxon	Lake Nicolet			Lake George	
	Rapids	Littoral	Offshore	Littoral	Offshore
Ephemeroptera					
Ameletus sp.		10		166	
Caenis sp.		1,155	80	1,284	132
Ephemera simulians		20	774	11	199
Ephemerella sp.		3	69	43	
Hexagenia limbata		47	762	95	6,206
Leptophlebia sp.	3,770	7	26	222	181
Stenonema tripunctatum	2,270				
Trichoptera					
Ceraclea sp.		29	3		
Cheumatopsyche sp.	3,003				
Grammotaulus sp.		201			
Phryganea sp.		38			263
Phylocentropus sp.			14	12	64
Polycentropus sp.		280	229	97	186
Trianodes sp.		38	38	11	38
Other Trichoptera		53	27	39	39
Hemiptera					
Sigara cornuta		1,368	19	43	
Odonata					
Aeshna canadensis				4,767	
Arigomphus sp.				2,633	
Enallagma boreale		127		428	
Lestes disjunctus		134			
Libellula sp.				176	

(Continued)

Table 29. (Concluded).

Taxon	Lake Nicolet Rapids	Lake Nicolet Littoral	Lake Nicolet Offshore	Lake George Littoral	Lake George Offshore
Diptera					
Chironomidae					
Ablabesmyia sp.		90	1,069	412	
Cryptochironomus sp.		537	466	331	552
Larsia sp.		596	299	488	158
Paratanytarsus sp.		1,200	305	35	
Polypedilum sp.		1,520	2,205	839	1,197
Procladius sp.		1,192	1,045	594	659
Psectrocladius sp.		155	50	274	25
Stictochironomus sp.		452	55	95	10
Other Chironomidae	3,330	2,923	704	2,900	280
Simulidae					
Simuliam sp.	112	6	8		
Amphipoda					
Hyalella azteca		2,250	2,228	812	912
Gammarus fasciatus		354	85	111	129
Isopoda					
Asellus intermedia		2,777	25	645	117
Lirceus sp.		1,008	984	306	792
Decapoda					
Orconectes propinqus	11,200				
Gastropoda		123	237	108	406
Pelecypoda					
Spaeriidae		144	397	53	4,347
Oligocheata					
Stylaria fossularis		2,045			
Other Oligocheata		1,464	2,003	291	1,468
Miscellaneous taxa		2,336	563	1,800	857
Totals	23,683	24,682	14,464	20,020	18,846

littoral areas, and good water quality similar to the St. Marys River, were optimal habitat for percid communities. The St. Marys River is richer in species than the Precambrian Shield lakes considered by Ryder and Kerr (1978) and contains northern redbelly dace (*Phoxinus eos*) and brook stickleback (*Culea inconstans*), species usually considered mutually exclusive with percid communities because of their association with bogs. However, the greater diversity of fishes (Table 30) in the St. Marys River is a reflection of the river's varied habitats as well as its connections with the oligotrophic fish communities of Lakes Superior and Huron.

Primary fish habitats of the St. Marys River are (1) the open-water main stem

Table 30. Fishes identified from the St. Marys River (compiled from various sources).

Scientific name	Common name
PETROMYZONTIDAE	
Petromyzon marinus	Sea lamprey
Lampetra lamottei	American brook lamprey
ACIPENSERIDAE	
Acipenser fulvescens	Lake sturgeon
LEPISOSTEIDAE	
Lepisosteus osseus	Longnose gar
AMIIDAE	
Amia calva	Bowfin
CLUPEIDAE	
Alosa pseudoharengus	Alewife
Dorosoma cepedianum	Gizzard shad
SALMONIDAE	
Coregonus artedii	Lake herring
Coregonus clupeaformis	Lake whitefish
Prosopium cylindraceum	Round whitefish
Salmo gairdneri	Rainbow trout
Salmo trutta	Brown trout
Salmo salar	Atlantic salmon
Salvelinus fontinalis	Brook trout
Salvelinus namaycush	Lake trout
Salvelinus fontinalis x namaycush	Splake
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus kisutch	Coho salmon
Oncorhynchus tshawytscha	Chinook salmon
OSMERIDAE	
Osmerus mordax	Rainbow smelt
UMBRIDAE	
Umbra limi	Central mudminnow
ESOCIDAE	
Esox lucius	Northern pike
Esox masquinongy	Muskellunge
CYPRINIDAE	
Carassius auratus	Goldfish
Couesius plumbeus	Lake chub
Cyprinus carpio	Carp
Hybopsis storeriana	Silver chub
Nocomis micropogon	River chub
Notemigonus crysoleucas	Golden shiner
Notropis atherinoides	Emerald shiner
Notropis cornutus	Common shiner

(Continued)

Table 30. (Continued).

Scientific name	Common name
Notropis heterodon	Blackchin shiner
Notropis heterolepis	Blacknose shiner
Notropis hudsonius	Spottail shiner
Notropis stramineus	Sand shiner
Notropis volucellus	Mimic shiner
Phoxinus eos	Northern redbelly dace
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Rhinichthys atratulus	Blacknose dace
Rhinichthys cataractae	Longnose dace
Semotilus atromaculatus	Creek chub
CATOSTOMIDAE	
Catostomus catostomus	Longnose sucker
Catostomus commersoni	White sucker
Moxostoma anisuram	Silver redhorse
Moxostoma erythrurum	Golden redhorse
Moxostoma macrolepidotum	Shorthead redhorse
ICTALURIDAE	
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
ANGUILLIDAE	
Anguilla rostrata	American eel
CYPRINODONTIDAE	
Fundulus diaphanus	Banded killifish
GADIDAE	
Lota lota	Burbot
GASTEROSTEIDAE	
Culea inconstans	Brook stickleback
Gasterosteus aculeatus	Threespine stickleback
Pungitius pungitius	Ninespine stickleback
PERCOPSIDAE	
Percopsis omiscomaycus	Trout-perch
PERCICHTHYIDAE	
Morone chrysops	White bass
CENTRARCHIDAE	
Ambloplites rupestris	Rock bass
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis nigromaculatus	Black crappie

(Continued)

Table 30. (Concluded).

Scientific name	Common name
PERCIDAE	
Etheostoma exile	Iowa darter
Etheostoma nigrum	Johnny darter
Perca flavescens	Yellow perch
Perca caprodes	Logperch
Stizostedion canadense	Sauger
Stizostedion vitreum vitreum	Walleye
SCIAENIDAE	
Aplodinotus grunniens	Freshwater drum
COTTIDAE	
Cottus bairdi	Mottled sculpin
Cottus cognatus	Slimy sculpin
Cottus ricei	Spoonhead sculpin
Myoxocephalus quadricornis	Fourhorn sculpin

portion and embayments of the river, (2) emergent wetlands bordering more protected reaches, (3) sand and/or gravel beaches, and (4) the St. Marys Rapids. Many species are associated with more than one of these habitats or may move among habitats on a diel or seasonal basis. However, each habitat supports a collection of species which distinguishes it from other habitats (Table 31).

Open-water areas of the St. Marys River provide a heterogeneous environment for fishes despite the outward appearance of uniformity. Variations in depth and substrate character occur both longitudinally from the upper to lower river and horizontally across the river. Depth, in turn, influences both water temperature and turbidity, with the greatest turbidity occurring near tributary mouths. Water currents are strongest and unidirectional in shipping channels in the main stem, becoming weaker and under greater wind influence away from these channels in embayments (U.S. Army Corps of Engineers 1984). In addition, seasonal meteorological and hydrologic cycles influence these abiotic environmental factors. Water temperature, hydrologic patterns, water quality, depth, and substrate conditions in combination with more subtle biotic and abiotic influences largely determine the fish species present and their distribution within the open-water habitats of the river.

Overall, the fish community of open-water areas is dominated by demersal species, and only two pelagic species, lake herring (*Coregonus artedii*) and rainbow smelt (*Osmerus mordax*), contribute substantially in relative abundance (Tables 32 and 33). Smaller species and juveniles of species which attain larger sizes are most effectively sampled with otter trawls in the open-water habitat (Liston et al. 1981, 1983). Among smaller species, trout-perch (*Percopsis omiscomaycus*), johnny darter (*Etheostoma nigrum*), and spottail shiner (*Notropis hudsonius*) are most abundant throughout the river (Table 32). Yellow perch are the most common juvenile fishes in open-water habitats.

In the upper river adjoining White-fish Bay, clear water and sandy substrates favor johnny darter and ninespine stickleback (*Pungitius pungitius*), species that are also abundant in the other Upper Great Lakes (Scott and Crossman 1973). Mottled sculpin (*Cottus bairdi*) and juvenile yellow perch are abundant (>10% of total number) in the upper river as well. Below the rapids, both trout-perch and spottail

Table 31. Fifteen most abundant fishes in each of five habitat types ranked from most (1) to least (15) abundant (Liston et al. 1980, 1983, 1986).

	Habitat						
		Non-Veg.	Veg.	Offshore			
				trawl		gill net	
Species	Beach	Shore	Shore	1.5 m	3.0 m	1.5 m	3.0 m
	Rank						
Trout-perch	1	15	13	1	1	13	8
Bluntnose minnow	--	8	9	10	13	--	--
Carp	--	--	--	--	--	12	14
Common shiner	4	14	14	--	--	--	--
Emerald shiner	2	1	4	11	11	--	--
Golden shiner	10	--	--	--	--	--	--
Lake chub	9	--	--	--	--	--	--
Longnose dace	12	--	--	--	--	--	--
Mimic shiner	5	2	5	5	3	--	--
Spottail shiner	3	4	1	2	2	11	13
Johnny darter	11	--	--	4	6	--	--
Logperch	--	--	--	13	14	--	--
Yellow perch	8	6	8	3	4	5	6
Walleye	6	--	--	--	--	6	5
Black crappie	--	7	7	7	10	--	--
Bluegill	--	3	2	--	--	--	--
Rock bass	7	12	12	8	9	7	7
Smallmouth bass	--	13	15	--	--	14½	15
Silver redhorse	14	--	--	--	--	--	--
White sucker	15	9	10	6	7	1	1
Rainbow smelt	13	11	11	14	15	2	2
Brown bullhead	--	10	6	--	--	10	9½
Ninespine stickleback	--	--	--	12	8	--	--
Brook stickleback	--	--	--	15	12	--	--
Mottled sculpin	--	--	--	9	5	--	--
Lake herring	--	--	--	--	--	4	3
Lake whitefish	--	--	--	--	--	14½	12
Pink salmon	--	--	--	--	--	9	9½
Northern pike	--	--	--	--	--	3	4
Alewife	--	--	--	--	--	8	11
Gizzard shad	--	5	3	--	--	--	--

shiner are abundant everywhere, while mimic shiner (Notropis volucellus), white sucker, and mottled sculpin are most numerous in the narrower channels of the middle river. Below Neebish Island, the river contains large embayments and open shoreline areas, as does Lake George. These open shoreline areas are utilized by spawning trout-perch (Magnuson and Smith 1963) and also appear to favor spottail shiner. Below the rapids, johnny darter and juvenile yellow perch are abundant in Lake George, while black crappie (Pomoxis nigromaculatus) are common only in the lower river below Munuscong Lake (Table 32).

Larger fishes collected with gill nets also exhibit distributional patterns among river reaches (Table 33). In the upper river, rainbow smelt, yellow perch, and the ubiquitous white sucker predominate (Greenwood 1983b; Liston et al. 1986). Lake whitefish are also more common in the

Table 32. Percent composition (by number) of 15 most abundant fishes collected with a 4.9-m otter trawl at the 1.5 and 3.0-m depth contours in open-water habitats of the upper, middle, and lower St. Marys River and Lake George Basin (Liston et al. 1980, 1983, 1986).

Species	Upper river	Middle river	Lake George	Lower river
Rainbow smelt	0.4	1.8	1.7	4.2
Bluntnose minnow	0	0.3	0.4	1.6
Emerald shiner	0	0.8	T[a]	2.6
Mimic shiner	0	18.1	T	4.7
Spottail shiner	0.2	13.0	19.1	15.7
White sucker	4.2	5.2	3.8	2.2
Trout-perch	0.2	13.7	36.2	45.4
Brook stickleback	2.8	3.2	1.0	0.3
Ninespine stickleback	31.3	6.3	1.6	0.3
Mottled sculpin	12.8	11.6	0.4	1.2
Black crappie	T	0.1	T	3.3
Rock bass	0.1	2.6	1.3	1.7
Yellow perch	14.0	6.9	15.6	8.1
Johnny darter	32.4	9.6	10.0	6.5
Logperch	T	3.7	2.0	0.9
Cumulative %	98.3	96.9	97.1	98.7
Total fish	4,005	9,441	3,234	20,248
Number samples	26	78	10	84
Average fish/sample	154.0	121.0	322.4	241.0

[a]T = <0.1%.

upper river than elsewhere. In the lower river, below the rapids, four species of fish--lake herring, northern pike, white sucker, and yellow perch--are common in most reaches (Schorfar 1975; Wolgemuth 1977; Miller 1979; Liston et al. 1980, 1981, 1986). Walleye are relatively abundant in Munuscong Lake and southward, less common from Munuscong Lake to the rapids, and were not collected above the rapids. Walleye are actually more abundant in the lower river and Potagannissing Bay during most of the year than Table 33 indicates, but move seasonally to summer feeding areas (see below). Another species common in the lower river but not collected above the rapids is brown bullhead (Ictalurus nebulosus. Although abundant in the St. Marys River, lake herring are presently on the threatened species list in Michigan (Mich. Dep. Nat. Resour. 1984).

Several of the more abundant fishes collected with gill nets are not resident species. Rainbow smelt move into the river from Lake Huron in spring to spawn when water temperatures are 4-5 °C and are only susceptible to gill nets for a brief period when migrating to spawning sites. However, dietary studies of piscivorous fish suggest that low numbers of rainbow smelt remain in the river through summer. Despite this, rainbow smelt are the second most abundant species collected from the river with gill nets (Liston et al. 1980, 1981, 1986). Lake herring also leave the river during mid- to late summer when water temperatures rise to near this specie's upper thermal limit of 20 °C (Dryer and Beil 1964). Pink salmon (Oncorhynchus gorbuscha) are only abundant in the river during the fall of odd-numbered years when most spawn. Pink salmon were accidentally introduced into Lake

Table 33. Percent composition (by number) of 15 most abundant fishes collected with experimental bottom gill nets in open-water habitats of the upper, middle, and lower St. Marys River, Lake George basin, Raber Bay, and Potagannissing Bay (Liston et al. 1980, 1983, 1986).

Species	Upper river	Middle river	Lake George	Lower river[a]	Raber Bay	Potagannissing Bay
Alewife	1.1	0.2	0.5	5.4	1.2	1.5
Lake herring	0.9	29.0	3.2	26.8	57.0	23.7
Lake whitefish	6.3	0.5	0	0.3	0.4	0.5
Pink salmon	0.7	1.7	0.8	T[a]	0	0
Rainbow smelt	32.4	5.7	1.2	8.6	10.7	4.5
Northern pike	7.9	11.7	21.8	10.6	6.0	5.1
Spottail shiner	2.0	0.3	2.6	1.0	--	--
White sucker	28.7	23.1	30.5	10.1	9.5	18.9
Brown bullhead	0	0.9	0.6	0.8	0.3	5.1
Trout-perch	1.1	1.4	0.5	0.6	--	--
Rock bass	0.7	7.1	6.9	2.8	0.7	4.7
Yellow perch	13.3	11.7	20.2	16.6	8.6	26.4
Walleye	0	3.5	3.8	14.1	4.2	5.1
Cumulative %	95.1	96.8	92.6	97.7	98.6	95.5
Total fish	457	2,661	652	3,562	885	3,542
Number samples	18	31	22	30	8	22
Average fish/sample	32.6	50.2	23.2	79.1	110.6	161.0

[a]T = <0.1%.

Superior from a hatchery. In the Pacific Ocean they spawn every other year. In Great Lakes, most spawning occurs in odd-numbered years, although spawning during even-numbered years has been documented.

Other species of interest not listed in Table 33 are smallmouth bass (Micropterus dolomieui), which are seasonally abundant in the lower river, chinook salmon (Oncorhynchus tshawytscha), and lake sturgeon (Acipenser fulvescens). Chinook salmon, another introduced Pacific salmon, move into the river from Lake Huron in August and September to spawn. Lake sturgeon occur throughout the river in low numbers (Wolgemuth 1977; Liston et al. 1986) and are presently on the threatened species list in Michigan.

The fish community of emergent wetlands is composed of a complex of Cyprinidae and juveniles of other species, with larger adult fish utilizing these habitats only seasonally or during diel foraging movements (Liston et al. 1983, 1986). Three species of shiners (emerald [Notropis atherinoides], spottail, and mimic) are abundant in most emergent wetland areas of the river (Table 34). Emerald shiners are rare only in Lake George wetlands. Other species composing >5% of the total fishes in wetlands are gizzard shad (Dorosoma cepedianum) in the lower river below Munuscong Lake and bluntnose minnow (Pimephales notatus), juvenile brown bullhead, bluegill (Lepomis macrochirus), and yellow perch in the middle river. Juvenile yellow perch also comprise >5% of the fishes in the Lake George wetlands (Table 34).

Habitat segregation by fishes of the St. Marys River is perhaps most clearly illustrated in juvenile bluegill whose distribution is restricted to emergent wetlands. Although juveniles are seasonally abundant in emergent wetlands,

neither juveniles nor adults were collected in open water areas during 5 years of sampling with a variety of gear types (Liston et al. 1980, 1981, 1983, 1986). Furthermore, bluegill are not reported in sport fishing catches from the river (D. Behmer, Lake Superior State college, Sault Ste. Marie, Michigan; pers. comm.). Liston et al. (1986) suggested that juvenile bluegill from the lower river could not be separated from pumpkinseed (Lepomis gibbosus). However, age I individuals collected from Lake Nicolet wetlands and reared in aquaria were bluegill (Duffy 1985). The absence of adult bluegill and distribution of juveniles pose interesting, but unresolved, questions regarding predation pressure on the local ecology of this species.

Within wetlands, microhabitat differences (such as differences in macrophyte density) are more easily discernable than are microhabitat variations in open-water communities. Liston and colleagues (1986) sampled fishes in both emergent macrophyte beds and in openings within or between beds. They found that the same species used each microhabitat, but a slightly different community composition existed in each area. In openings within emergent wetlands devoid of emergent plants, the three most abundant species were emerald shiner, mimic shiner, and bluegill. Within emergent macrophyte beds, the three most abundant species were spottail shiner, bluegill, and gizzard shad. Hart (1983) found that juveniles of both bluegill and rock bass (Ambloplites rupestris) preferred open areas within wetlands, but congregated along edges near emergent macrophytes.

A total of 44 species of fishes use wetlands in the St. Marys River. These wetlands serve as nursery areas for all

Table 34. Percent composition (by number) of 15 most abundant fishes collected with small experimental trap nets set along shore in open-water habitats of the upper, middle, and lower St. Marys River and the Lake George Basin (Liston et al. 1980, 1983, 1986).

Species	Upper river	Middle river	Lake George	Lower river
Gizzard shad	0.5	T[a]	0.1	8.2
Rainbow smelt	2.7	T	0	4.8
Bluntnose minnow	2.4	5.4	3.3	4.1
Common shiner	1.9	1.2	25.0	1.0
Emerald shiner	21.3	5.2	T	34.4
Mimic shiner	11.2	17.0	2.1	12.1
Spottail shiner	43.0	3.7	51.5	18.4
White sucker	6.8	4.3	1.2	0.5
Brown bullhead	0.3	14.3	1.5	1.2
Trout-perch	0.9	0.2	0.1	1.8
Black crappie	0	0.5	2.3	4.6
Bluegill	1.9	20.7	0.5	2.1
Rock bass	0.6	1.9	0.8	1.1
Smallmouth bass	T	1.6	0.5	0.8
Yellow perch	3.5	7.1	6.6	2.3
Cumulative %	97.0	83.1	95.5	97.4
Total fish	17,287	10,290	11,769	37,964
Number 24-h samples	26	28	36	26
Average fish/sample	665.0	368.0	327.0	1,460.0

[a]T =<0.1%.

the centrarchids plus yellow perch, northern pike, bowfin (Amia calva), longnose gar (Lepisosteus osseus), brown bullhead, and cyprinids, as well as other species. Adult fishes move into these areas on a diel basis to forage or rest. Adult walleye are sometimes collected in large numbers as they move into emergent wetlands to forage after dark (Liston et al. 1986). Yellow perch, conversely, move into wetlands at night to rest and may be observed lying on bottom within Scirpus beds (Duffy, pers. observ.). Finally, wetlands are used as spawning habitat by some of the more important fish species of the St. Marys River, such as northern pike, smallmouth bass, and yellow perch (see below).

Fish use of beach shoreline habitat has been investigated in the middle portion of the river from Lake Nicolet to Munuscong Lake, but use of similar habitats in other river reaches has not (Liston et al. 1980, 1981). The fish community found in these beach zones comprises species found in wetlands as well as small demersal species common in open-water areas (Table 35). Throughout the area sampled, the most common species collected in beach zones were trout-perch and emerald, spottail, common (Notropis cornutus), and mimic shiners. Juvenile walleye are also common in beach-zone habitats. Among beach zones sampled, walleye were most common near the mouth of the Charlotte River, a tributary to the St. Marys River, and lake chub (Couesius plumbeus) were collected only from a beach located on Chicken Island in the Middle Neebish Channel.

The fish community inhabiting the St. Marys Rapids is discrete from the fish communities of other parts of the river. Unfortunately, these rapids are so large as to defy quantitative sampling methods and most of the information available is from sportfishing harvests. However, Gleason et al. (1981) did obtain quantitative samples of fish, using the U.S. Army Corps of Engineers power canal and tailrace paralleling the upper rapids. The rapids have been a locus of fishing activity from pre-European times to the present (see Chapter 1). Ernest Hemingway, who fished these rapids in the 1920's, is said to have called the rapids "the best rainbow trout fishing in the world ... second only in strenuousness to angling for tuna off Catalina Island ..." (Damman 1972).

Table 35. Average number of fish collected with a 61.5-m beach seine along exposed shoreline areas of the St. Marys River on St. Joseph Island, Chicken Island, and at Dunbar Research Station during 1979 and 1980. (Liston et al. 1980, 1981).

Species	Year 1979	Year 1980
Alewife	0.3	0
Rainbow smelt	1.9	0.2
Northern pike	0.2	0
Lake chub	1.4	1.4
Blacknose shiner	0	0.4
Common shiner	6.0	3.0
Emerald shiner	3.7	21.4
Golden shiner	2.7	0
Mimic shiner	2.9	2.4
Rosyface shiner	0	0.4
Spottail shiner	6.7	12.8
Blacknose dace	0	0.2
Longnose dace	1.6	0.6
White sucker	1.3	0.2
Silver redhorse	1.1	0.6
Shorthead redhorse	0.2	0
Brown bullhead	0.5	0
Trout-perch	14.1	11.6
Mottled sculpin	1.0	0
Slimy sculpin	0	0.2
Rock bass	1.2	2.0
Yellow perch	1.9	1.0
Walleye	2.1	1.8
Johnny darter	1.0	1.4
Logperch	0.3	0.2
Other species	0.2	0
Number of species	26	20
Average fish/seine	53.7	61.8
Number of seines	21	5
Total fish	1,127	309

Principal fish species caught in the rapids by anglers are lake whitefish (Coregonus clupeaformis) and rainbow trout (Salmo gairdneri) in roughly equal proportions (Koshinsky and Edwards 1983). Lake (Salvelinus namaycush), brown (Salmo trutta), and brook trouts (Salvelinus fontinalis) are also caught in the rapids.

During autumn, walleye and chinook salmon move into the rapids area. Koshinsky and Edwards (1983) list 38 species of fish which have been collected from the rapids. Among these, the abundant forage species are longnose dace (Rhinichthys cataractae) and slimy sculpin (Cottus cognatus). Another species of interest, the sea lamprey (Petromyzon marinus), is also abundant in the rapids.

In the power canal adjacent the rapids, white and longnose suckers (Catostomus catostomus) were the most common species collected (Gleason et al. 1981). Other species collected in the power canal which are characteristic of the rapids habitat include chinook salmon during the spawning season and occasional brook trout.

Ichthyoplankton and spawning. Ichthyoplankton studies in the St. Marys River have identified 39 separate species (Table 36; Liston et al. 1980, 1981, 1983, 1986; Gleason et al. 1981; Duffy 1985; Jude et al. 1986). Fish larvae collected in the river consist not only of larvae from fish inhabiting the river, but also larvae from fish resident in tributaries and Whitefish Bay. The predominance of rainbow smelt larvae in samples attests to the importance of tributary and Whitefish Bay contributions to the river's ichthyofauna. Rainbow smelt spawn in small tributaries or along rocky shorelines. However, Jude et al. (1986) found drift of larvae from the upper to lower river through the Edison Sault power canal was minimal. The ichthyoplankton fauna in all reaches of the river is dominated by rainbow smelt (Gleason et al. 1981; Liston et al. 1986). A marked seasonal succession of fish larvae is apparent though, (Figure 40) and is the result of differential timing of reproduction by various species in response to environmental stimuli (Liston et al. 1980).

At ice-out in spring the ichthyoplankton population consists of larvae from fall- or winter-spawning lake herring, lake white-fish, burbot (Lota lota), and fourhorn sculpin (Myoxocephalus quadricornis; Figure 40). Soon after ice-out,

Table 36. Fish larvae collected in the St. Marys River (Liston et al. 1980, 1981, 1986; Ashton, unpubl. data).

Scientific name	Common name
Peptromyzontidae	
Lampetra sp.	Brook lamprey
Petromyzon marinus	Sea lamprey
Amiidae	
Amia calva	Bowfin
Clupeidae	
Alosa pseudoharengus	Alewife
Salmonidae	
Coregonus artedii	Lake herring
Coregonus clupeaformis	Lake whitefish
Onchorhynchus gorbuscha	Pink salmon
Osmeridae	
Osmerus mordax	Rainbow smelt
Umbridae	
Umbra limi	Central mudminnow
Esocidae	
Esox lucius	Northern pike

(Continued)

Table 36. (Concluded).

Scientific name	Common name
Cyprinidae	
Cyprinus carpio	Carp
Notemigonus crysoleucus	Golden shiner
Notropis cornutus	Common shiner
Notropis atherinoides	Emerald shiner
Notropis volucellus	Mimic shiner
Notropis hudsonius	Spottail shiner
Notropis sp.	Unidentified shiner
Pimephales spp.	Unidentified minnow
Catostomidae	
Catostomus commersoni	White sucker
Moxostoma sp.	Unidentified redhorse
Ictaluridae	
Ictalurus nebulosus	Brown bullhead
Cyprinodontidae	
Fundulus diaphanus	Banded killifish
Gadidae	
Lota lota	Burbot
Gasterosteidae	
Pungitius pungitius	Ninespine stickleback
Percopsidae	
Percopsis omiscomaycus	Trout-perch
Centrarchidae	
Ambloplites rupesris	Rockbass
Lepomis macrochirus	Bluegill
Lepomis gibbosus	Pumpkinseed
Lepomis spp.	Unidentified sunfish
Micropterus dolomieui	Smallmouth bass
Sciaenidae	
Aplodinotus grunniens	Freshwater drum
Percidae	
Etheostoma nigrum	Johnny darter
Etheostoma sp.	Unidentified darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
Percina sp.	Unidentified darter
Stizostedion vitreum	Walleye
Cottidae	
Cottus sp.	Unidentified sculpin
Myoxocephalus quadricornis	Fourhorn sculpin

beginning in May to early June, larvae of spring-spawning species, such as rainbow smelt, yellow perch, and white sucker, appear and dominate the ichthyoplankton community. Larvae of summer-spawning Cyprinidae and other species, such as bluegill, pumpkin seed, and alewife (*Alosa pseudoharengus*) appear in samples from late June through the remainder of summer (Figure 39).

Distinct habitat associations are exhibited by many of these fish larvae as well as other species for which quantitative information is difficult to obtain (Table 37). Goodyear et al. (1982) compiled information on spawning and nursery areas for the St. Marys River. Although much of the information presented in their report was anecdotal, their findings generally support field studies. Species which spawn in tributaries and drift downstream to the St. Marys River, such as rainbow smelt, white sucker, and burbot, are usually more abundant at offshore sites than at nearshore ones (Table 37). However, white sucker larvae are abundant at both offshore and nearshore sites, which may reflect an affinity for more protected habitats. Dense schools of white sucker larvae may be observed drifting down tributaries in early summer, normally concentrated within 1-2 m of the tributary bank. Larvae of fishes that spawn in emergent wetlands, including cyprinids, bluegill, and yellow perch, generally are much more abundant near this habitat than elsewhere (Table 37). Larvae of other fish that spawn in wetlands remain in these habitats until they are quite mobile and are, therefore, underestimated in sampling. Examples from the St. Marys River include northern pike, smallmouth bass, bowfin, common carp (*Cyprinus carpio*), and central mudminnow (*Umbra limi*).

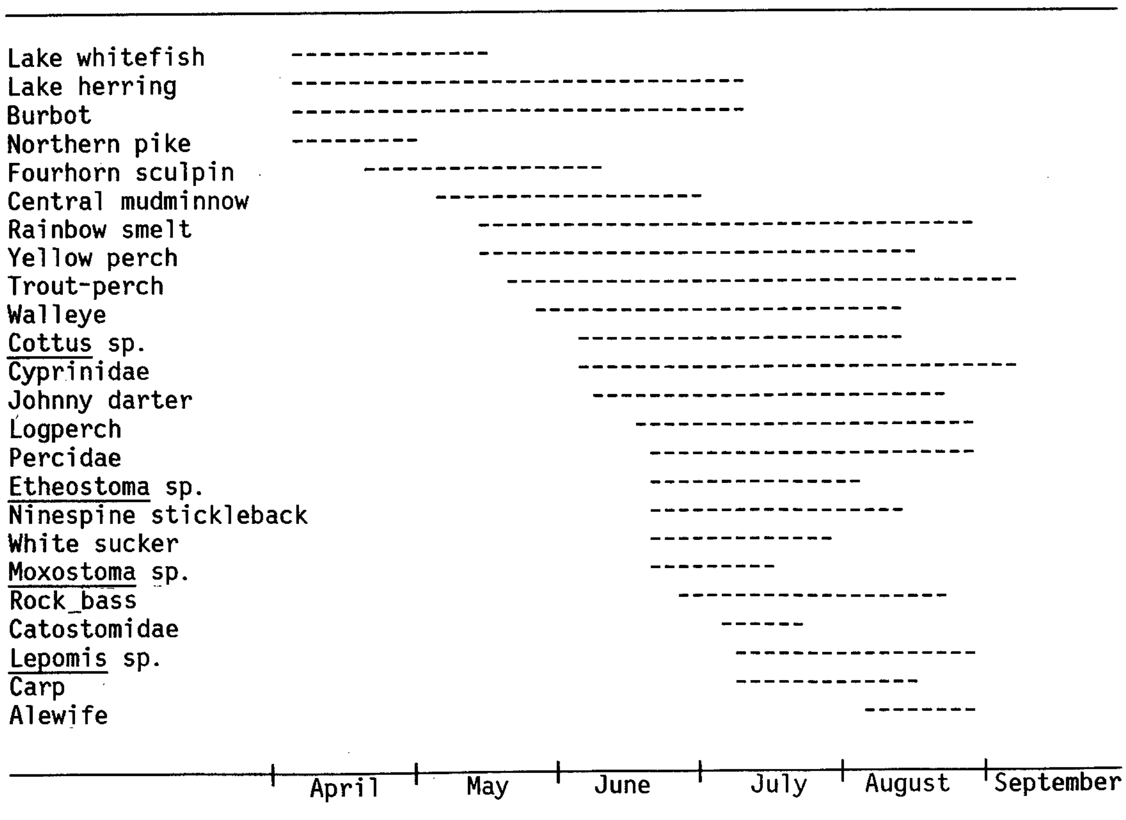


Figure 40. Seasonal occurrence of larval fish in the St. Marys River.

Table 37. Fish larvae collected from each of three habitat types in the St. Marys River during 9 April through 28 September 1981 as a percent of the total (Liston et al. 1980, 1983, 1986)

Species	Habitat and depth		
	Shore 0.5 m	Mid-depth 1.5-2 m	Navigation channel 9-10 m
	Percent of total		
Lake herring	1.0	1.3	0.3
Lake whitefish	2.9	0.3	<0.1
Alewife	0	0.3	2.7
Rainbow smelt	1.3	69.2	69.9
Central mudminnow	0	0.1	0
Carp	3.4	3.1	1.1
Cyprinidae	32.3	9.0	0.8
Catostomidae (cf. white sucker)	12.4	1.4	11.3
Burbot	0.4	4.8	8.0
Trout-perch	0.1	0.2	0.5
Ninespine stickleback	0	0.2	0.4
Rock bass	0.1	0.1	0
Lepomis sp.	23.1	0.7	0.1
Johnny darter	2.8	1.2	1.1
Yellow perch	10.2	3.8	0.4
Logperch	10.0	4.0	1.5
Cottus sp.	0.1	0.5	1.8
Fourhorn sculpin	0	0	0.2
Total no./100m^3 water	338.4	58.3	22.0
Total no. collected	1,569	3,897	3,133

The majority of species in a percid community like the St. Marys River--lake whitefish, white sucker, longnose sucker, silver redhorse (*Moxostoma anisuram*), shorthead redhorse (*M. macrolepidotum*), walleye, trout-perch, and several species of cyprinids--spawn over or on exposed rock, gravel, or rubble in well-oxygenated water (Balon 1975). Other species such as brown bullhead and sculpins spawn in holes or cavities and guard their nests. Still other species, including species of centrarchids and sticklebacks, build nests.

The presence of wetland areas enables species which use vegetation in spawning to reproduce and maintain populations in the river. Yellow perch spawn in wetlands, including those of the St. Marys River, draping egg masses over vegetation. Northern pike and central mudminnows spawn in wetlands very near the water's edge. These species have adhesive eggs which attach to either live or dead vegetation, and their larvae are adapted to low-oxygen conditions, which occur where decomposing aquatic macrophytes form a thick organic layer over bottom sediments (Balon 1975).

Movement of fishes. Many of the fish species inhabiting the river undertake seasonal movements from one area to another. For some species these movements only amount to a seasonal dispersal into adjoining habitats. However, for other species, such as lake herring and walleye, these seasonal movements may be characterized as migration because they are a periodic departures from and returns to an area (Odum 1971).

Several investigators have attempted to quantify winter movement of fishes in the shipping channel of the St. Marys River using remote sensing techniques (Behmer and Gleason 1975; Dahlberg et al. 1980). However, in each of these studies results have been undermined by an inability to collect fish from the shipping channel in order to "ground truth" recorded data. Each study was conducted in late winter and recorded a preponderance of pelagic fish. Dahlberg et al. (1980) suggested that many of the fish they recorded were possibly rainbow smelt beginning to move toward tributary streams in preparation for spawning.

Other information on migration and dispersal of fish in the river comes from mark and recapture studies of adult fishes by Liston et al. (1986). In this study, 14,946 fish were tagged and released, with 452 recovered at later dates. Fish tagged were generally hardier species that could withstand the handling required for this type of study. White sucker, yellow perch, rock bass, smallmouth bass, and brown bullhead moved relatively short distances before being recaptured, generally <5 km. Northern pike were also sedentary during most of the year, moving greater distances during the spring spawning period, and also randomly undertaking extensive movements on occasion. In contrast to the sedentary nature of these species, walleye were found to undertake seasonal migration within the river. Liston et al. (1986) found that walleye undertook extensive prespawning movement toward Munuscong Lake, a known walleye spawning location, where most of the fish were tagged during winter and early spring (Figure 41A). Beginning in summer, a postspawning dispersal away from Munuscong Lake was also undertaken by walleye (Figure 41B). Average distance traveled by walleye before being recaptured was 14 and 17 km in the 2 years of this study. However, larger fish undertook much more extensive movements than small fish (Liston et al. 1986).

Other fish undertaking seasonal movements or migration in the St. Marys River are chinook salmon, pink salmon, lake herring, and sea lamprey. Sea lamprey will be treated separately later because of their unique role in the Great Lakes.

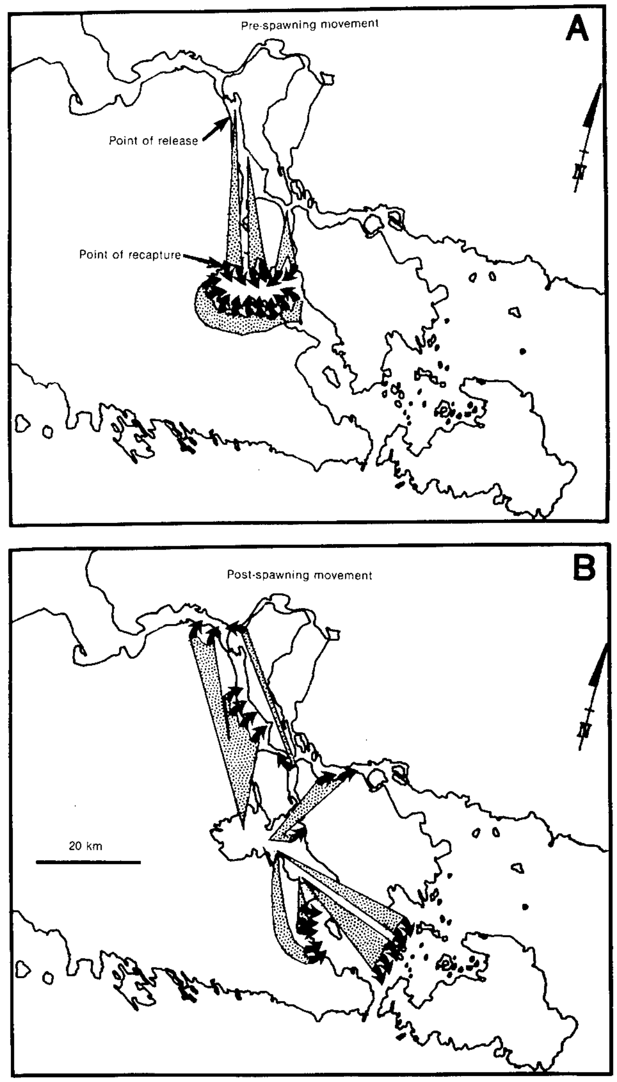


Figure 41. (A) Movement of walleye in the St. Marys River towards Munuscong Lake during January-February and (B) dispersal from the lake in July-August 1983 (Liston et al. 1986).

Chinook salmon were introduced to the river in 1975 by the Michigan Department of Natural Resources, and a population is maintained through periodic stocking operations (J. Schorfar, Mich. DNR, Newberry; pers. comm.). Adult chinook salmon are in the river for only a brief period during late summer and autumn when they return from Lake Huron, moving up the river to the rapids area where they were stocked.

Pink salmon also inhabit the river for a brief period in late summer and fall as adults. However, unlike other Pacific salmon, in the Great Lakes most pink salmon only spawn every other year. Also, unlike Atlantic salmon (Salmo salar) and other Pacific salmon which were introduced to the Great Lakes to create a sport fishery, pink salmon were accidentally introduced to Lake Superior in 1956 (Scott and Crossman 1973), but now spawn in most of the tributaries to the St. Marys River.

Lake herring inhabit the river during most of the year and exhibit two types of movement, one associated with feeding and another in physiological response to water temperature. In October and November when water temperature nears 4-5 °C lake herring move into the river to spawn. Most migrate from Lake Huron and probably the North Channel. Following spawning, fish remain in the river through winter and spring until late June or early July. At this time, water temperature usually approaches 20 °C, the upper thermal limit for lake herring, and the fish move from the river to deeper areas. During some years, dispersal from these shallower habitats precedes the mass emergence of burrowing mayflies and lake herring will return for several weeks to feed, then again disperse (Duffy and Liston 1981).

Sea lamprey. The sea lamprey is one of many accidentally introduced species now thriving in the Great Lakes. However, unlike other species, sea lamprey are parasitic on and predators of other large fishes. Sea lamprey are anadromous and in spring move up rivers or streams until locating gravel or rubble substrate in which to spawn (Applegate 1950). After hatching, their ammocoetes burrow out of the nest and drift downstream, settling in soft silt or mud substrates where they burrow in tail first and remain for a variable period of time (Scott and Crossman 1973). During the ammocoete phase, sea lamprey are particle feeders and only become parasitic/predaceous after completing transformation to the adult phase.

The introduction of sea lamprey to the Great Lakes brought about massive changes to the indigenous fish community. Already stressed by commercial fishing pressure, lake trout were nearly extirpated by sea lamprey predation (Lawrie 1978). Secondary species also affected included lake whitefish, lake herring, and other fish large enough to be preyed upon. Efforts to control sea lamprey in the Great Lakes began in the 1940's and eventually led to the development of the chemical lampricide TFM, now widely used to treat streams where ammocoetes are identified. The sea lamprey problem also encouraged the formation of the International Great Lakes Fishery Commission by the United States and Canada.

Sea lamprey spawn in the St. Marys River at the St. Marys Rapids, tributaries to the river, and probably at lesser rapids located below Lakes Nicolet and George (Daugherty et al. 1984; Heinrich, U.S. Fish Wildl. Serv., Marquette, Michigan; pers. comm.). For sea lamprey control purposes, the St. Marys River is considered a tributary to Lake Huron. The St. Marys River population of sea lamprey is sizable, and 20% of the adults captured from Lake Huron tributaries in 1983 were taken at the St. Marys Rapids (Daugherty et al. 1984). The adult population in the river appears to have remained stable in recent years. Catch of adult sea lamprey in assessment traps at the rapids almost doubled after 1981 (Table 38). However, increased catches are the result of changes in waterflow at sampling sites (Whittle, Ontario Min. Nat. Resour., Burlington; pers. comm.).

Table 38. Number of adult sea lamprey caught in assessment traps below the U.S. Army Corps of Engineers hydroelectric generating plant at Sault Ste. Marie, Michigan (Daugherty and Purvis 1985).

Year	Total number
1977	1,419
1978	1,148
1979	1,213
1980	1,995
1981	1,954
1982	3,848
1983	3,999

Ammocoete populations also appear to be expanding in the St. Marys River. Recent surveys located 1,134 sea lamprey ammocoetes in the river, with most of these collected in the Lake Nicolet reach (Figure 42; Daugherty and Purvis 1985). Unlike most streams used by sea lamprey for spawning, the St. Marys River is large and its considerable volume prevents treatment with chemical lampricides. Since this population is probably contributing significantly to the northern Lake Huron population, recent recommendations to the International Great Lakes Fishery Commission have included exploring alternative methods of controlling sea lamprey in larger rivers.

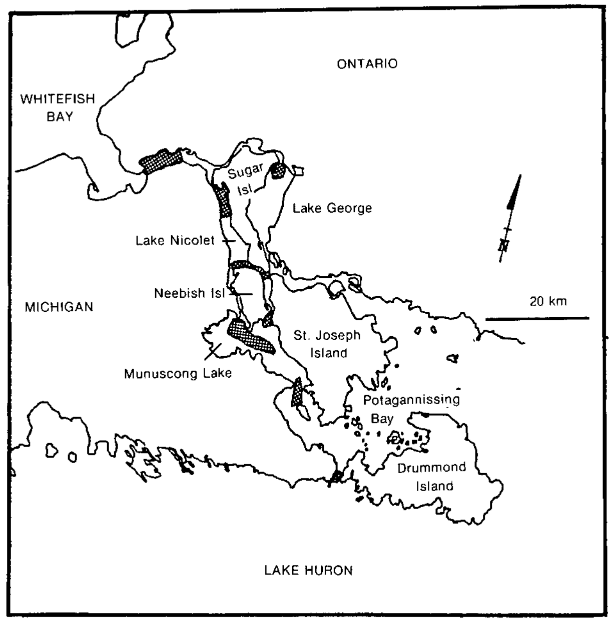


Figure 42. Distribution of sea lamprey ammocoetes in the St. Marys River (Daugherty et al. 1984).

Amphibians and Reptiles

The amphibian and reptile communities of the St. Marys River are rather depauperate and no studies specific to the river have been published. The range of 29 species of amphibians and reptiles encompasses the river and these are listed in Table 39. Herdendorf et al. (1981)

Table 39. Amphibians and reptiles observed and potentially occurring in the St. Marys River and vicinity (Connant 1975; Duffy, unpubl. data).

Scientific name	Common name
TESTUDINES	
Chelydridae	
Chelydra serpentina	Snapping turtle
Emydidae	
Clemmys insculpta	Wood turtle
Chrysemys picta marginata	Midland painted turtle[a]
Chrysemys picta belli	Western painted turtle
SQUAMATA	
Colubridae	
Nerodia sipedon sipedon	Northern water snake
Thamnophis sirtalis sirtalis	Eastern garter snake[a]
Thamnophis sauritus septentrionalis	Northern ribbon snake
Storeria occipitomaculata occipitomaculata	Northern red-bellied snake[b]
Storeria dekayi dekayi	Northern brown snake
Diadophis punctatus edwardsi	Northern ringneck snake[a]
Opheodrys vernalis vernalis	Eastern smooth-green snake

(Continued)

Table 39. (Concluded).

Scientific name	Common name
Lampropeltis triangulum triangulum	Eastern milk snake
Viperidae	
Sistrurus catenatus catenatus	Eastern massasauga[b]
CAUDATA	
Necturidae	
Necurus maculosus	Mudpuppy[a]
Salamanridae	
Notophthalmus viridescens viridescens	Red-spotted newt[a]
Notophthalmus viridescens louisianensis	Central newt
Ambystomatidae	
Ambystoma laterale	Blue-spotted salamander
Ambystoma maculatum	Spotted salamander
Plethodontidae	
Plethodon cinereus cinereus	Red-backed salamander[a]
Hemidactylium scutatum	Four-toed salamander
ANURA	
Bufonidae	
Bufo americanus	American toad[a]
Hylidae	
Hyla crucifer	Northern spring peeper[a]
Hyla versicolori - Hyla chrysoscelisa	Gray tree frog[a]
Ranidae	
Rana clamitans melanota	Green frog
Rana catesbeiana	Bullfrog[a]
Rana pipiens	Northern leopard frog[a]
Rana palustris	Pickeral frog
Rana sptentrionalis	Mink frog
Rana sylvatica	Wood frog[a]

[a]Species identified from the immediate vicinity of the river.
[b]Species whose northern edge of geographic range is at the southern edge of the St. Marys River Basin.

listed 17 species as probable inhabitants of emergent wetlands along the river based on records for Chippewa County, Michigan, in Ruthven (1928). However, only 12 species have been positively identified from the river.

Jefferson's salamander (Ambystoma jeffersonianum) was among the species Ruthven (1928) recorded for Chippewa County. However, this record is in question because the northern range limit of Jefferson's salamander is now considered to extend from middle New York State to northern Indiana (Conant 1975), far south of the St. Marys River area.

Birds

The St. Marys River and surrounding area support a rich community of birds. Of the 172 known species of the area (Table 40), waterfowl, colonial waterbirds, shorebirds, some raptors, and passerine birds are intimately associated with the river. Others are associated

Table 40. Birds observed in the vicinity of the St. Marys River (Duffy unpubl. data; Weise unpubl. data).

Scientific name	Common name
GAVIIFORMES	
Gaviidae	
Gavia immer	Common loon
PODICIPEDIFORMES	
Podicipedidae	
Podilymbus podiceps	Pied-billed grebe
Podiceps auritus	Horned grebe
PELECANIFORMES	
Phalacrocoracidae	
Phalacrocorax auritus	Double-crested cormorant
CICONIFORMES	
Ardeidae	
Botaurus lentiginosus	American bittern
Ixobrychus exilis	Least bittern
Ardea herodias	Great blue heron
Butorides striatus	Green-backed heron
ANSERIFORMES	
Anatidae	
Cygnus columbianus	Tundra (whistling) swan
Anser albifrons	Greater white-fronted goose
Chen caerulescens	Snow goose
Branta bernicla	Brant
Branta canadensis	Canada goose
Aix sponsa	Wood duck
Anas crecca	Green-winged teal
Anas discors	Blue-winged teal
Anas rubripes	American black duck
Anas platyrhynchos	Mallard
Anas acuta	Northern pintail
Anas strepera	Gadwall
Aythya valisineria	Canvasback
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya affinis	Lesser scaup
Histrionicus histrionicus	Harlequin duck
Clangula hyemalis	Oldsquaw
Melanitta fusca	White-winged scoter
Melanitta nigra	Black scoter
Bucephala albeola	Bufflehead
Bucepnala clangula	Common goldeneye

(Continued)

Table 40. (Continued).

Scientific name	Common name
Mareca americana	American wigeon
Lophodytes cucullatus	Hooded merganser
Mergus merganser	Common merganser
Mergus serrator	Red-breasted merganser
FALCONIFORMES	
Cathartidae	
Cathartes aura	Turkey vulture
Accipitridae	
Pandion haliaetus	Osprey
Haliaeetus leucocephalus	Bald eagle
Circus cyaneus	Northern harrier
Accipiter striatus	Sharp-shinned hawk
Accipiter cooperii	Cooper's hawk
Accipiter gentilis	Northern goshawk
Buteo lineatus	Red-shouldered hawk
Buteo platypterus	Broad-winged hawk
Buteo jamaicensis	Red-tailed hawk
Buteo lagopus	Rough-legged hawk
Falconidae	
Falco sparverius	American kestrel
Falco columbarius	Merlin
Falco peregrinus	Peregrine falcon
Falco rusticolus	Gyrfalcon
GALLIFORMES	
Phasianidae	
Dendragapus canadensis	Spruce grouse
Bonasa umbellus	Ruffed grouse
Tympanuchus phasianellus	Sharp-tailed grouse
Meleagris gallopavo	Wild turkey
GRUIFORMES	
Rallidae	
Rallus limicola	Virginia rail
Porzana carolina	Sora (rail)
Gallinula chloropus	Common (gallinule) moorhen
Fulica americana	American coot
Gruidae	
Grus canadensis tabida	Greater sandhill crane
CHARADRIIFORMES	
Charadriidae	
Pluvialis squatarola	Black-bellied plover
Pluvialis dominica	Lesser golden plover

(Continued)

Table 40. (Continued).

Scientific name	Common name
Charadrius semipalmatus	Semipalmated plover
Charadrius vociferus	Killdeer
Scolopacidae	
Tringa melanoleuca	Greater yellowlegs
Tringa flavipes	Lesser yellowlegs
Actitis macularia	Spotted sandpiper
Bartramia longicauda	Upland plover
Arenaria interpres	Ruddy turnstone
Calidris minutilla	Least sandpiper
Calidris alpina	Dunlin
Gallinago gallinago	Common snipe
Scolopax minor	American woodcock
Laridae	
Larus philadelphia	Bonaparte's gull
Larus delawarensis	Ring-billed gull
Larus argentatus	Herring gull
Sterna caspia	Caspian tern
Sterna hirundo	Common tern
Chlidonias niger	Black tern
COLUMBIFORMES	
Columbidae	
Columba livia	Rock dove
Zenaida macroura	Mourning dove
CUCULIFORMES	
Cuculidae	
Coccyzus erythropthalmus	Black-billed cuckoo
STRIGIFORMES	
Strigidae	
Otus asio	Eastern screech owl
Bubo virginianus	Great horned owl
Nyctea scandiaca	Snowy owl
Athene cunicularia	Burrowing owl
Strix varia	Barred owl
Strix nebulosa	Great gray owl
Asio flammeus	Short-eared owl
Aegolius acadicus	Northern saw-whet owl
CAPRIMULGIFORMES	
Caprimulgidae	
Chordeiles minor	Common nighthawk
Caprimulgus vociferus	Whip-poor-will

(Continued)

Table 40. (Continued).

Scientific name	Common name
APODIFORMES	
Apodidae	
Chaetura pelagica	Chimney swift
Trochilidae	
Archilochus colubris	Ruby-throated hummingbird
TROGONIFORMES	
Alcedinidae	
Ceryle alcyon	Belted kingfisher
PICIFORMES	
Picidae	
Sphyrapicus varius	Yellow-bellied sapsucker
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Colaptes auratus	Northern flicker
Dryocopus pileatus	Pileated woodpecker
PASSERIFORMES	
Tyrannidae	
Contopus borealis	Olive-sided flycatcher
Empidonax minimus	Least flycatcher
Savornis phoebe	Eastern phoebe
Myiarchus crinitus	Great crested flycatcher
Tyrannus tyrannus	Eastern kingbird
Contopus virens	Wood pewee
Alaudidae	
Eremophila alpestris	Horned lark
Hirundinidae	
Progne subis	Purple martin
Tachycineta bicolor	Tree swallow
Riparia riparia	Bank swallow
Hirundo pyrrhonota	Cliff swallow
Hirundo rustica	Barn swallow
Stelgidopteryx ruficollis	Rough-winged swallow
Corvidae	
Perisoreus canadensis	Gray jay
Cyanocitta cristata	Blue jay
Corvus brachyrhynchos	American crow
Corvus corax	Common raven
Paridae	
Parus atricapillus	Black-capped chickadee
Parus hudsonicus	Boreal chickadee
Parus bicolor	Tufted titmouse

(Continued)

Table 40. (Continued).

Scientific name	Common name
Sittidae	
Sitta canadensis	Red-breasted nuthatch
Sitta carolinensis	White-breasted nuthatch
Certhiidae	
Certhia americana	Brown creeper
Troglodytidae	
Troglodytes aedon	House wren
Troglodytes troglodytes	Winter wren
Cistothorus platensis	Sedge wren
Cistothorus Palustris	Marsh wren
Muscicapidae	
Regulus satrapa	Golden-crowned kinglet
Regulus calendula	Ruby-crowned kinglet
Sialia sialis	Eastern bluebird
Catharus fuscescens	Veery
Catharus ustulatus	Swainson's thrush
Hylocichla mustelina	Wood thrush
Turdus migratorius	American robin
Mimidae	
Dumetella carolinensis	Gray catbird
Toxostoma rufum	Brown thrasher
Bombycillidae	
Bombycilla cedrorum	Cedar waxwing
Laniidae	
Lanius excubitor	Northern shrike
Lanius ludovicianus	Loggerhead shrike
Sturnidae	
Sturnus vulgaris	European starling
Vireonidae	
Vireo philadelphicus	Philadelphia vireo
Vireo olivaceus	Red-eyed vireo
Vireo gilvus	Warbling vireo
Vireo solitarius	Solitary vireo
Emberizidae	
Vermivora perigrina	Tennessee warbler
Vermivora ruficapilla	Nashville warbler
Dendroica petechia	Yellow warbler
Dendroica pensylvanica	Chestnut-sided warbler
Dendroica tigrina	Cape May warbler
Dendroica palmarum	Palm warbler
Dendroica nigrescens	Black-throated blue warbler
Dendroica virens	Black-throated green warbler
Dendroica dominica	Yellow-throated warbler
Dendroica magnolia	Magnolia warbler
Dendroica coronata	Yellow-rumped warbler
Dendroica castanea	Bay-breasted warbler
Dendroica fusca	Blackburnian warbler
Oporonis philadelphia	Morning warbler
Mniotilta varia	Black-and-white warbler

(Continued)

Table 40. (Concluded).

Scientific name	Common name
Motacilla ruticilla	American redstart
Piranga olivacea	Scarlet tanager
Pheucticus ludovicianus	Rose-breasted grosbeak
Passerina cyanea	Indigo bunting
Spizella passerina	Chipping sparrow
Spizella pallida	Clay-colored sparrow
Passerculus sandwichensis	Savannah sparrow
Passerella iliaca	Fox sparrow
Melospiza melodia	Song sparrow
Melospiza georgiana	Swamp sparrow
Zonotrichia leucophrys	White-crowned sparrow
Junco hyemalis	Dark-eyed junco
Calcarius lapponicus	Lapland longspur
Plectrophenax nivalis	Snow bunting
Dolichonyx oryzivorus	Bobolink
Agelaius phoeniceus	Red-winged blackbird
Euphagus carolinus	Rusty blackbird
Euphagus cyanocephalus	Brewer's blackbird
Quiscalus quiscula	Common grackle
Molothrus ater	Brown-headed cowbird
Fringillidae	
Pinicola enucleator	Pine grosbeak
Coccothraustes vespertinus	Evening grosbeak
Carpodacus purpureus	Purple finch
Loxia curvirostra	Red crossbill
Carduelis flammea	Common redpoll
Carduelis pinus	Pine siskin
Carduelis tristis	American goldfinch
Passeridae	
Passer domesticus	House sparrow

with riparian areas along or upland habitats adjacent to the river, while still other species are temporary inhabitants during spring and fall migration.

Waterfowl. Waterfowl use the St. Marys River for breeding and rearing young. Both ducks and geese migrate through the area to and from breeding areas further north in spring and fall (Figures 43-45). Ducks and geese first arrive in spring, usually during late March or early April. Robinson and Jensen (1980) reported that mallards (*Anas platyrhynchos*) began returning to the river on 21 and 26 March in two consecutive years, common mergansers (*Mergus merganser*) also returned in late March, and black ducks (*Anas rubripes*) arrived slightly later in early April. Before initiating nesting, both ducks and geese feed in the nearby flooded grain fields and extensive wetlands bordering the river. Important Canada geese (*Branta canadensis*) feeding areas are located on western St. Joseph Island and east of Lake George (Ont. Min. Nat. Resour. 1985). Both dabbling ducks and geese concentrate in grain fields west of Munuscong Lake at this time (Duffy, pers. observ.).

Nesting on the river and in lakes throughout the region begins about 1 month

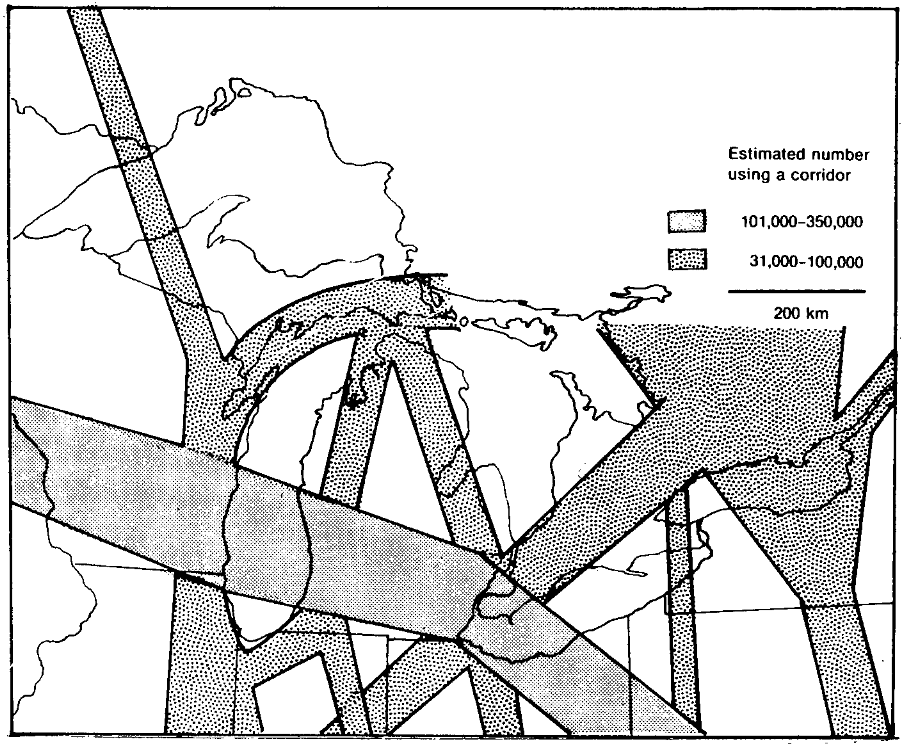


Figure 43. Major migration corridors for dabbling ducks through the Great Lakes region (Bellrose 1968).

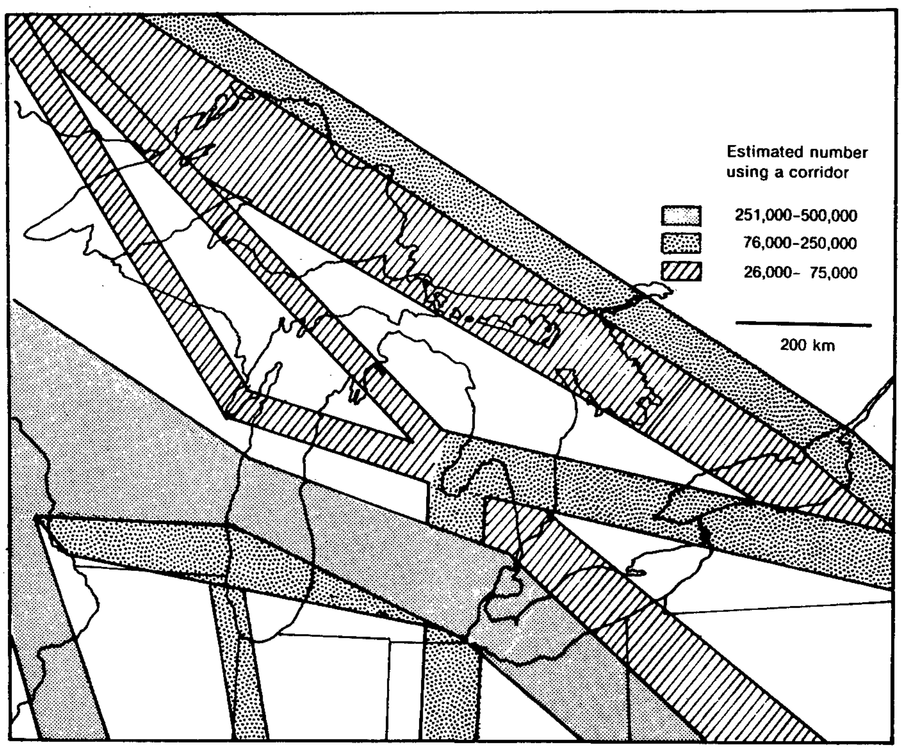


Figure 44. Major migration corridors for diving ducks through the Great Lake region (Bellrose 1968).

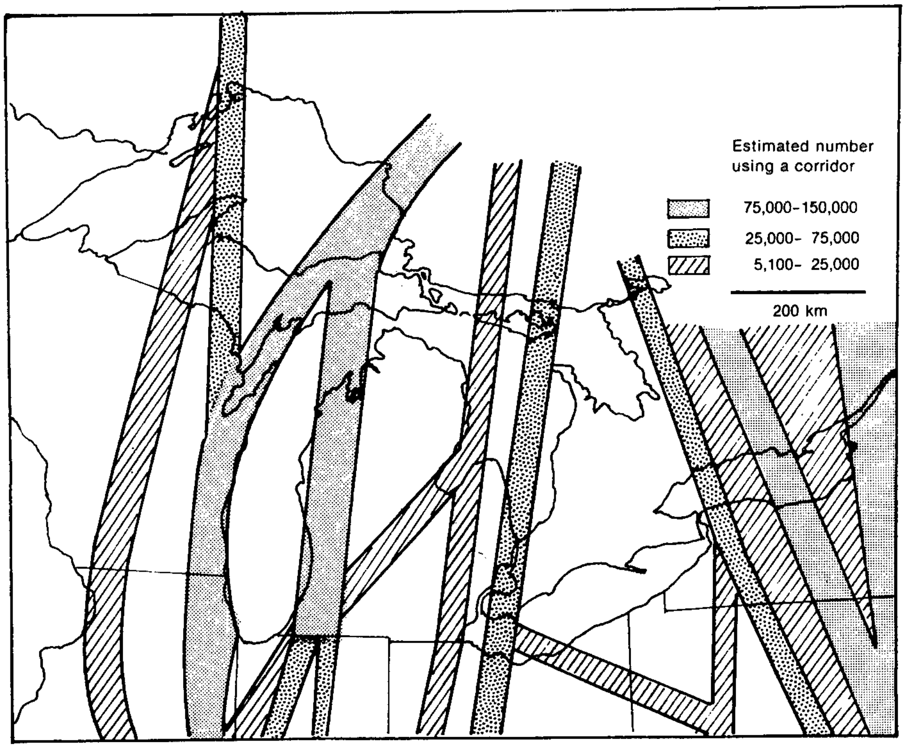


Figure 45. Major migration corridors for geese through the Great Lake region (Bellrose 1968).

after arrival, and initial broods appear in early June (Table 41). Concentrations of breeding waterfowl in the river's fringing marshes appear to be similar to concentrations in inland wetlands in the general region. During a 20-year period, Weise (1985) found density of breeding pairs of ducks averaged 8.9/km^2 in Munuscong Lake marshes (Figure 46). These pairs produced an average of 8.4 ducklings per brood during the 20-year period (Weise 1985). In a 100 km^2 area of boreal forest bordering the northeast edge of the river, density of breeding pairs of ducks averaged from 5.3 to 9.4/km^2 in 1980 (McNicol and Ross 1982). McNicol and Ross (1982) found the average mortality of ducklings through age class III--that is, from hatching to just before flight capability--ranged from 49%-78% among species. Sources of mortality, however, were not identified.

Species of ducks nesting in Munuscong Lake marshes were common goldeneye (Bucephala clangula), mallard, blue-winged teal (Anas discors), and black duck (Weise 1985). American wigeon (Mareca americana) and common mergansers were uncommon in the Munuscong Lake marsh, but common mergansers do nest and are abundant in other areas of the river. Other waterfowl commonly nesting in the emergent wetlands bordering the river include American coots (Fulica americana) and Canada geese, plus occasional northern pintails (Anas acuta) and common loons (Gavia immer). Many of these species use the marshes well into fall at which time they are joined by species such as ring-necked ducks (Aythya collaris) staging for southward migration (Table 42).

Fall migration from the river begins with the departure of blue- and green-winged teal (Anas crecca) in September, followed by most dabbling ducks in October. Diving ducks begin to move through the area in October, and by late October or early November the river is

Table 41. Mean dates of nest initiation and initial sightings of Class IA duck broods in boreal lakes on the northern edge of the St. Marys River (McNicol and Ross 1982). In class IA broods, young are down-covered and 1-7 days old.

Species	Mean nest initiation date	Mean date of initial class IA brood siting
Common goldeneye	1 May	15 June
Hooded merganser	20 April	11 June
Common merganser	4 May	25 June
Ring-necked duck	8 June	14 July
Mallard/Black duck	unknown	10 June

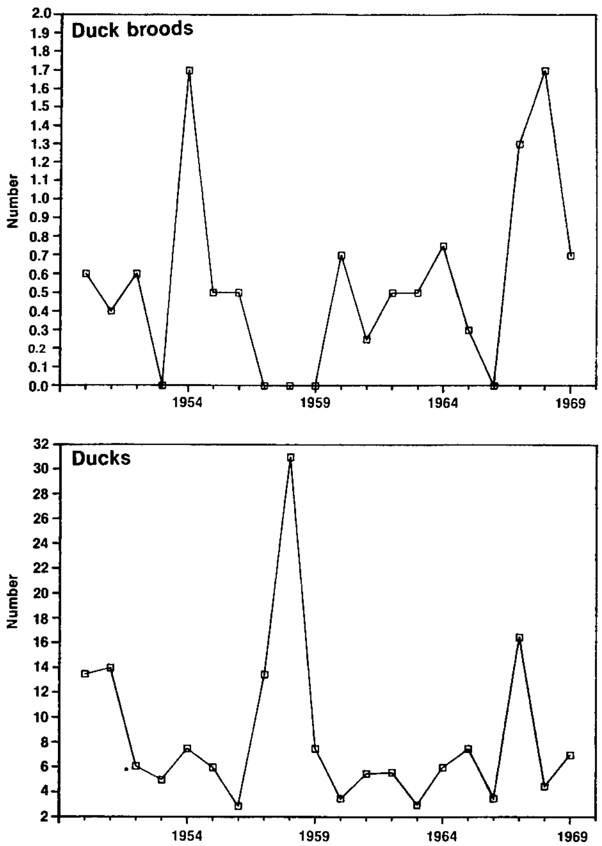


Figure 46. Number of duck broods and ducks in Munuscong lake waterfowl management area, 1950-69 (Weise, Michigan Department of Natural Resources, unpubl. data).

host primarily to scaup (Aythya affinis and A. marila) and redhead (A. americana; Table 43; Ceolin 1980; Weise 1985a). Several areas on the river are heavily used by rafting scaup, redhead, and other waterfowl (Figure 47).

Recovery of waterfowl banded in the St. Marys River indicates that most migrate from the river to the east or southeast United States (Figure 48A-D). The greatest number of mallard and black ducks are recovered from Michigan and Ontario, but both tend to radiate away from the river in a southern and eastern direction (Figure 48A, B). Teal appear to move in a more south-southwest direction, while greater and lesser scaup migrate to the Atlantic and Gulf of Mexico coasts (Figure 48C, D).

The most common species of waterfowl present in the St. Marys River during winter are common goldeneye, common merganser, and mallards (Figure 49; Robinson and Jensen 1980). Overwintering black ducks were also present in low numbers during the winters of 1978-79 and 1979-80 (Table 44). Additional species using the river during winter were bufflehead (Bucephala albeola), harlequin ducks (Histrionicus histrionicus), and wood ducks (Aix sponsa) but each species was represented by fewer than 10 individuals (Robinson and Jensen 1980). Canada geese were observed in low numbers through the

Table 42. Number of species of waterfowl using the Munuscong Lake Waterfowl Management Area during October and November of 1982 through 1984 as determined from aerial surveys (Weise 1985a).

Species	1982 Oct.	1982 Nov.	1983 Oct.	1983 Nov.	1984 Nov.
Wood duck	50	10	4		
Mallard	500	108	25	9	
Black duck	125		20	7	
Blue-winged teal	35				
Ring-necked duck	994	3,700	140	51	400
Bufflehead	100	67	50	18	75
Common goldeneye			10	4	
Hooded merganser			10	3	
Canada goose	250	27	8	4	
Others[a]		81			
Number of survey flights	2	1	1	1	1

[a]Other species recorded in November 1982 include gadwall, black duck, pintail, and hooded merganser.

winter of 1978-79 and increased to between 50 and 80 birds in spring, but were not recorded on the river during the winter of 1979-80 (Jensen 1980; Robinson and Jensen 1980).

Several areas of water which remain open throughout winter were found to be important to wintering waterfowl. These included (1) the rapids area, (2) an area along the Sault Ste. Marie, Ontario, shore below the rapids, extending 3-5 km either side of Bellevue Park, and (3) the outflow area of Edison Sault Electric Company's hydroelectric plant. Mallards, black ducks, and Canada geese used the area along the Ontario shore, while common goldeneye and common mergansers used the rapids, hydroelectric plant outflow, and any open water areas which appeared in the channel north of Sugar Island (Robinson and Jensen 1980). Other open water areas which exist in the river during winter are the "rock cut," where swift water currents maintain an open channel, and De Tour Passage. Neither of these sites was heavily used by waterfowl during the winters that Robinson and Jensen (1980) surveyed the river.

Wintering waterfowl apparently select their sites based primarily on open water and secondarily on food availability (Jensen 1980; Robinson and Jensen 1980). Mallards, black ducks, and Canada geese congregated around Bellevue Park where they were fed corn by people visiting the park. Common mergansers and common goldeneye used the hydroelectric outflow for roosting and the rapids area for feeding.

Colonial waterbirds and shorebirds. The many islands of the St. Marys River are extensively used by colonial waterbirds and shorebirds. Colonial waterbirds nest on these islands and feed in either open-water areas of the river or its marshes.

The most common colonial waterbirds associated with the river are ring-billed gulls (*Larus delawarensis*) and common terns (*Sterna hirundo*; Table 45). Population trends of these species and other colonial waterbirds in the St. Marys River have been shifting in recent years primarily because of rising water levels in the Great Lakes (brought about by increased precipitation) and cooler

Table 43. Number and species of waterfowl using the St. Marys River during November from 1979 through 1984 as determined from aerial surveys (Weise 1985a).

Common name	Year					
	1979	1980	1981	1982	1983	1984
American wigeon	75[a]		25	25		
Gadwall	75[a]					
Mallard	100[a]		100	765		
Black duck	100[a]		50	550		
Canvasback	75	3		7	10	
Redhead	7,400	3,400	550	2,800	900	1,600
Ring-necked duck	300	250		50	1,050	900
Scaup[b]	4,800	2,200	1,200	5,025	2,350	1,965
Oldsquaw	200	30		215	150	370
Black scoter	50					100
Bufflehead	200	65	75	130	50	350
Common goldeneye		120	50	135	50	175
Common merganser	25[c]	100[c]	25[c]	213		
Red-breasted merganser				212		
Hooded merganser				266		350
Canada goose			100	78	230	
American coot	700					
Common loon				22		25
Number of survey flights	2	1	1	2	1	1

[a]Includes average from composite figure for American wigeon, gadwall, mallard, and black duck at Munuscong Bay.

[b]Scaup includes both greater and lesser scaup.

[c]Common and red-breasted mergansers listed only as mergansers during 1979-81.

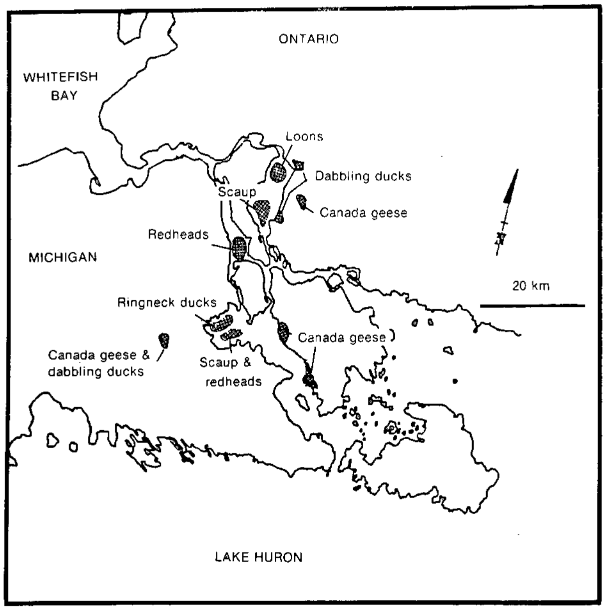


Figure 47. Areas of waterfowl concentration in the St. Marys River during fall and spring. Concentrations of Canada geese and dabbling ducks inland are during spring; all others are full concentrations (Weise, unpubl. MS.; E. Thomas, Ontario Ministry of Natural Resources unpubl. data).

summers which have reduced evaporation (Table 46; Scharf 1981; Scharf and Shugart 1985). Common terns, once more common, have been declining in numbers throughout the Great Lakes while ring-billed gull populations have increased. Scharf (1981) found this trend to be intensified in parts of the St. Marys River where shipping traffic accelerates the erosion of dredged material islands used by colonial waterbirds for nesting. As erosion and increasing water levels decrease the amount of habitat available to colonial waterbirds, the larger, earlier nesting ring-billed gulls displace common terns and other smaller species from nesting sites (Scharf 1977, 1978, 1981; Scharf and Shugart 1985).

Double-crested cormorants (Phalacrocorax auritus) are also increasing in numbers in the Upper Great Lakes, with this population now in the logarithmic phase of growth (Scharf and Shugart 1985). The success of double-crested cormorants is attributed to an abundant food supply, declines in chlorinated hydrocarbon pollution, and possibly protected nesting sites. In the St. Marys River, double-crested cormorants nest only in the upper river, although they may feed in other areas.

Two colonial waterbirds associated with marshes of the river are great blue herons (Ardea herodias) and black terns (Chlidonias niger). Great blue herons nest in trees on islands within the river from Lake George south to Potagannissing Bay (Figure 50) and feed in marshes on small fishes and amphibians. Black terns nest on rafts of dead emergent macrophytes within the river's emergent wetlands and feed in shallow-water areas of these marshes as well as in more open areas. Populations of both appear to be stable, but rising water levels are expected to have a negative effect on black terns by decreasing marsh-nesting habitat (Scharf 1978). Of the other colonial waterbirds, herring gulls are common throughout the river, while black-crowned night-herons (Nycticorax nycticorax) nest only at the mouth of the river.

Nesting success of colonial waterbirds is generally high. Scharf (1977) found that the percentage of eggs hatching among various species was generally in the 80%-90% range, the exception being those birds nesting on eroding islands. On these islands birds may be forced to select less favorable nesting sites, exposing their eggs and young to predators, or they may lose eggs to wave action (Scharf 1977). More recent work on common terns agrees with Scharf's results (Smith and Heinz 1984). Smith and Heinz (1984) found greatest nesting success on Raber Island, where 53 nests produced an average of 2.2 terns per nest, and Steamboat Island, which produced an average of 0.43 young per nest among 19 nests. Lime Island supported 209 nests, but no young terns were produced. High water levels and waves produced by ship traffic, along with natural wave action, are thought to be the reason for nest failure on Lime Island since no deformities were found in either chicks or embryos of St. Marys River common terns (Smith and Heinz 1984; T.J. Miller, U.S. Fish Wildl. Serv., Minneapolis, Minnesota, pers. comm.).

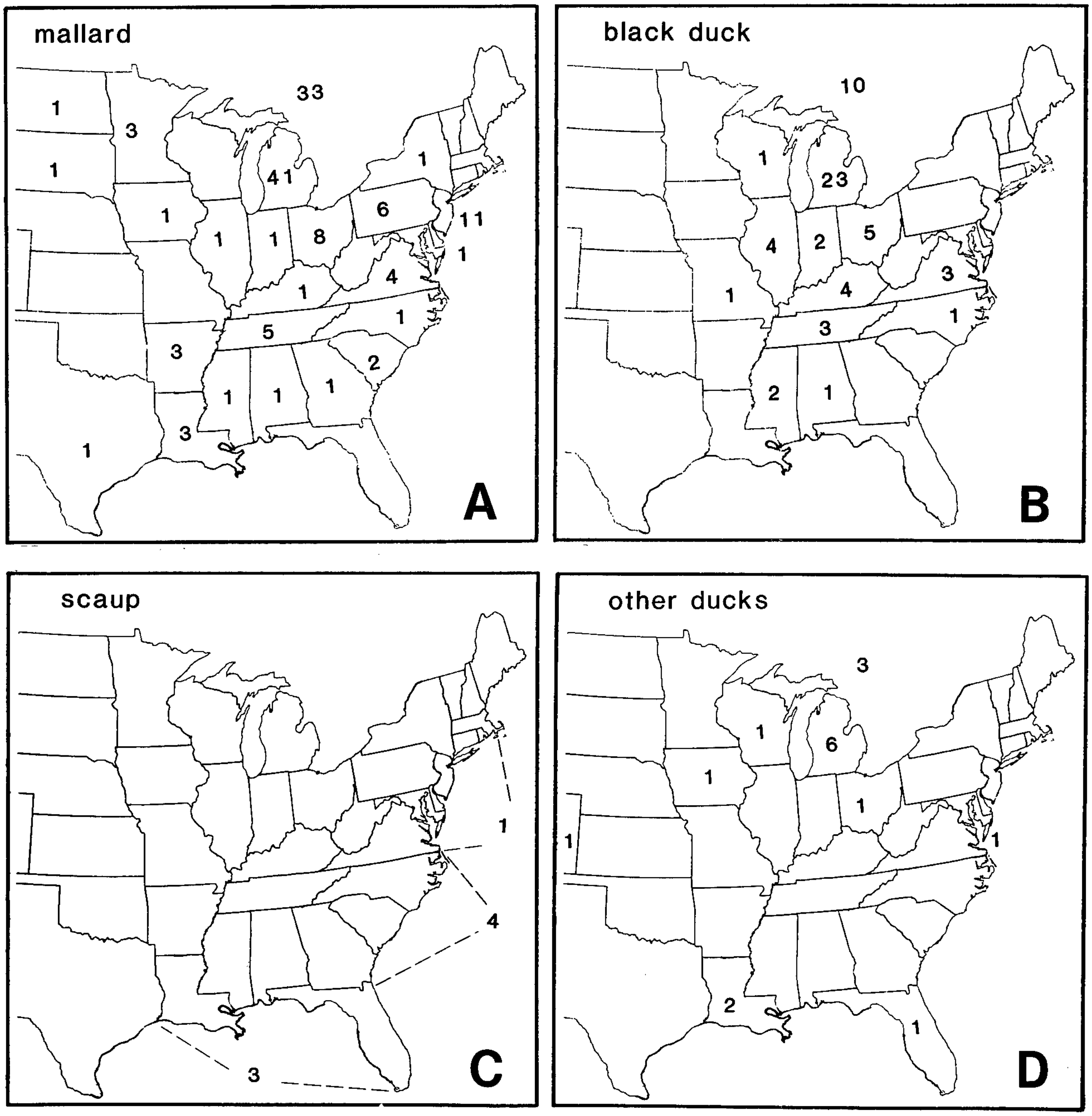


Figure 48. Recovery patterns of mallards, black ducks, scaup, and other ducks banded in the St. Marys River during 1963-78, showing number of ducks recaptured in each State or region (Weise, unpubl. MS.)

Common name	Year 1979	Year 1980
Common goldeneye[a]	350	370
Bufflehead[a]	50	30
Common merganser[a]	150	300
Red-breasted merganser	15	10
Hooded merganser	12	25
Mallard[a]	440	480
Black duck[a]	25	23
Blue-winged teal	1	0
Greater and lesser scaup	150	2,000
Ring-necked duck	8	25
American wigeon	8	3
Harlequin duck[a]	1	2
Wood duck	1	0
Canada goose[a]	50	80
Snow goose (blue phase)	1	0

[a]Species present in January and February.

Table 44. Waterfowl observed and maximum numbers recorded in the St. Marys River during January through April, 1979 and 1980 (Robinson and Jensen 1980).

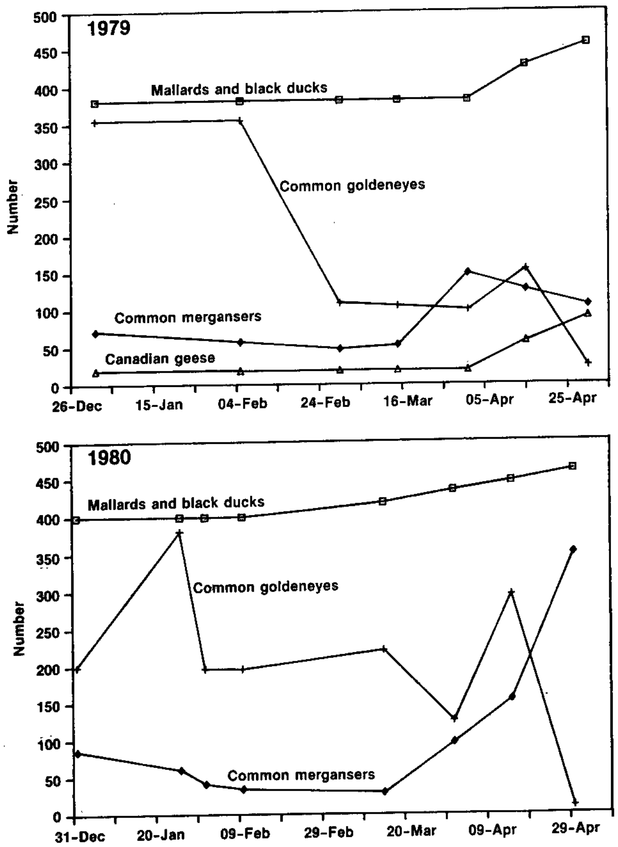


Figure 49. Population estimates for waterfowl using the St. Marys River during January through April, 1979 and 1980 (Robinson and Jensen 1980).

Table 45. Nesting habitat of colonial waterbirds in the St. Marys River. (Scharf 1977).

Common name	Nesting habitat
Herring gull	Bare rock, herbaceous vegetation, or heavy tree/shrub cover.
Ring-billed gull	Heavy silt/high clay substrates; does well on dredged material islands. May destroy vegetation on more porous soils.
Common tern	Bare, gravelly, sandy soil preferred.
Black tern	In marshes on matted vegetation.
Great blue heron	Tall deciduous trees, usually near marshes used for feeding.
Double-crested cormorant	In trees or on rock or gravel; may sometimes displace great blue heron.
Black-crowned night-heron	Young cottonwood trees preferred in other Great Lakes sites; specific information for St. Marys lacking.

Table 46. Estimated size of St. Marys River populations of common colonial waterbirds in 1976 and 1977 (Scharf 1978).

Common name	Year 1976	1977
Herring gull	1,690	1,650
Ring-billed gull	5,568	7,866
Common tern	434	379
Great blue heron	143	142

No quantitative information exists for shorebirds in the St. Marys River. However, increases in nesting sites indicate that greater sandhill cranes (*Grus canadensis tabia*) may have increased in numbers during recent years (Duffy, pers. observ.). Greater sandhill cranes nest and feed in wetlands along both the Michigan and Ontario shores of the river. They also use more inland areas on St. Joseph Island, Ontario, and open fields in Chippewa County, Michigan.

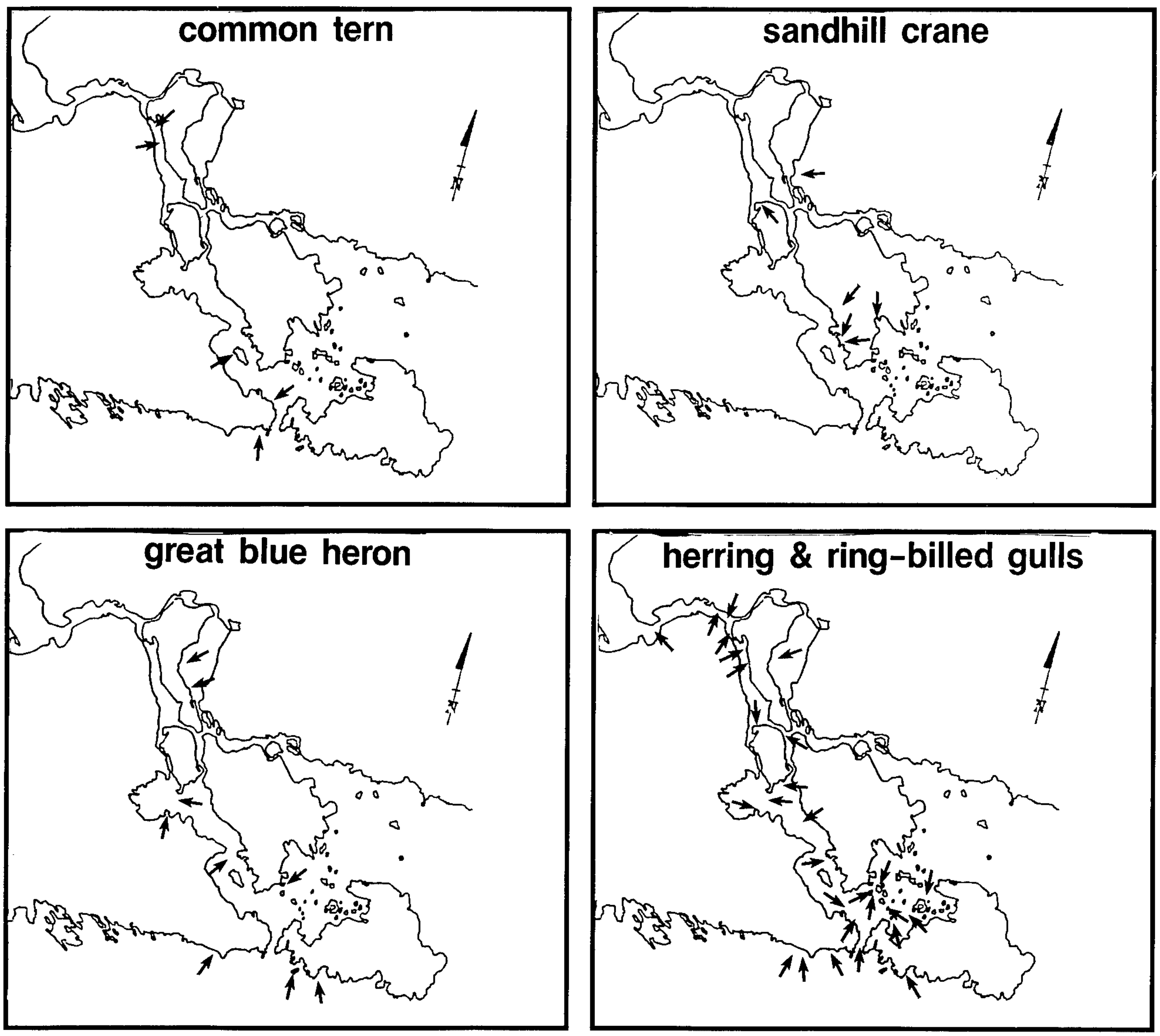


Figure 50. Nesting sites of colonial waterbirds in the St. Marys River area (Scharf 1978).

Another shorebird of interest is the piping plover (Charadrius melodus), a species recently placed on the Federal list of endangered species. Though it does not nest in the St. Marys River, one of the piping plover's few remaining nesting sites is located at nearby Vermilion Point, Lake Superior.

Raptors. The variety of habitat types associated with the St. Marys River attracts a number of raptors to this area as either seasonal or year-round residents or migrants (Table 40). Among the more conspicuous are northern bald eagles (Haliaeetus leucocephalus), osprey (Pandion haliaetus), snowy owls (Nyctea scandiaca), and great gray owls (Strix nebulosa). Rare species recorded from the vicinity of the river include the gyrfalcon (Falco rusticolus), peregrine falcon (F. peregrinus), and burrowing owl (Athene cunicularia). Some quantitative information exists for northern bald eagles and ospreys and for raptors using the river during winter months (Robinson and Jensen 1980; Weise 1985).

Northern bald eagles presently nest in two locations on Sugar Island (Weise 1985a) and the number of nests has remained stable over the past 13 years (Table 47). However, it is not known if the same nest sites have been used over this period or if the same pairs of eagles have been nesting. Nesting failure, common in the 1970's, declined in the 1980's, and 7 eaglets were produced during the 1981-85 period (Table 47).

Pairs of osprey nesting on the river increased dramatically between 1977 and 1982 and now appear to have stabilized at 15 or 16 nests (Table 47). As with northern bald eagles, the number of young osprey produced along the river showed a marked increase beginning in 1981. Adult osprey are commonly sighted along the river where they nest on navigational aids and hunt for fish in shallower water or at the surface in deeper water. Visual inspection of fish remains under nests revealed a high proportion of white sucker in summer and pink salmon in fall (Duffy, pers. observ.). Both osprey and northern bald eagle are listed as threatened species in Michigan; northern bald eagle is also listed as a threatened species by the U.S. Fish and Wildlife Service (Mich. DNR 1984; U.S. Fish Wildl. Serv. 1986).

Other common raptors associated with the river include barred owls (Strix

Table 47. Number of active and failed northern bald eagle and osprey nests and young of each produced from the St. Marys River from 1973 through 1985 (Weise 1985a).

	Osprey			Northern bald eagle		
Year	Active nests	Failed nests	Total young	Active nests	Failed nests	Total young
1973	1	0	2	0	0	0
1974	0	0	0	2	0	0
1975	5	3	7	2	2	0
1976	4	3	1	2	1	1
1977	4	2	4	1	1	0
1978	6	3	6	1	1	0
1979	9	4	8	1	1	0
1980	10	5	5	2	2	0
1981	12	4	15	2	0	2
1982	15	2	23	1	1	0
1983	15	4	21	1	0	2
1984	16	6	17	1	0	1
1985	15	n.d.	n.d.	2	0	2

varia), northern harrier (Circus cyaneus), broad-winged hawks (Buteo platypterus), and American kestrels (Falco sparverius). Northern harriers are common in wetlands and fields along the river's edge where they nest and feed. American kestrels are also common over fields and may often be seen perching on utility lines along roadways. These species are replaced by broad-winged hawks and barred owls in the spruce and hardwoods along the river and upland forests further back from the river's edge.

Seven species of raptors were found to inhabit the St. Marys River and its immediate vicinity during winter (Table 48; Jensen 1980; Robinson and Jensen 1980). Among these, northern bald eagles were most dependent on the river. Robinson and Jensen (1980) report that northern bald eagles and snowy owls were the only raptors consistently sighted in winter, though they noted that other observers had reported from three to six great gray owls in the area. During the winter of 1978-79 five great gray owls inhabited Neebish Island and several more were observed in separate locations within the Dunbar Forest adjacent to this island (Duffy, pers. observ.). Variable numbers of great gray owls continued to return to this area in winter through 1981.

Table 48. Number of raptors observed along the St. Marys River during January through April, 1979 and 1980 (Robinson and Jensen 1980).

Common name	Year 1979	Year 1980
Northern bald eagle	2	2
Goshawk	1	0
Rough-legged hawk	5	5
Red-tailed hawk	1	2
Gyrfalcon	1	0
Snowy owl	5	5
Great gray owl[a]	3-6	<4

[a]Number of great gray owls based on personal observations by Duffy.

Robinson and Jensen (1980) noted that a pair of bald eagles frequented the area around Sault Ste. Marie during the winters of 1977-78 and 1978-79 (Figure 51). They also sighted eagles at the south end of Sugar Island, but could not be certain if these were the same individuals frequenting Sault Ste. Marie or if those at Sault Ste. Marie were the same pair each winter since none were marked. Since their work, a second nest has been identified on Sugar Island, suggesting two pairs of northern bald eagles may winter in the area. Based on sighting, feeding observations, the distribution of open water, and previous studies, Robinson and Jensen (1980) estimated that the northern bald eagle's winter home range encompassed the Sugar Island area (Figure 52). Winter food consisted primarily of fish and waterfowl, but eagles appeared to be opportunistically feeding on other birds and carrion as well.

Passerine birds. Passerine birds are far more diverse than are the groups previously discussed. However, other than observational records, no information exists specific to passerine birds and

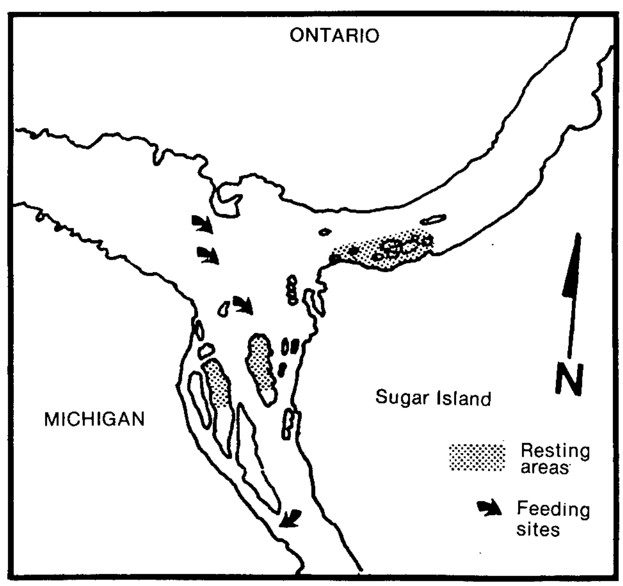


Figure 51. Areas of the St. Marys River used by northern bald eagles for nesting and feeding during winter, 1979 and 1980 (Robinson and Jensen 1980).

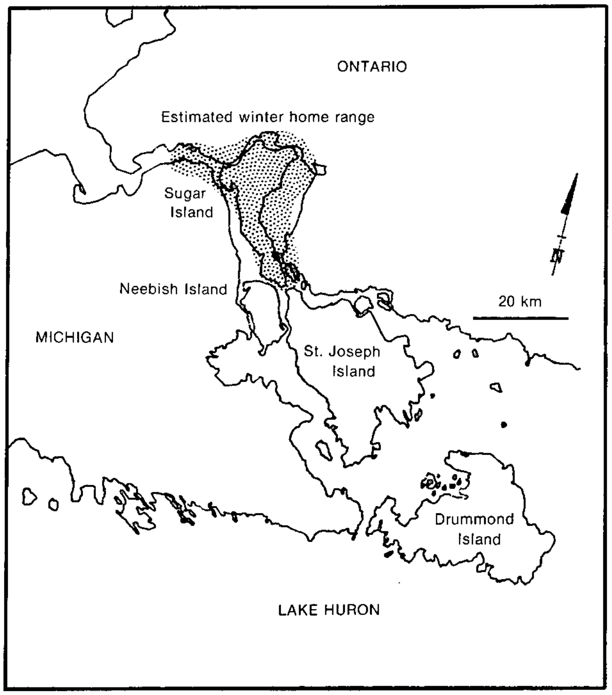


Figure 52. Estimated winter home range of northern bald eagle pair inhabiting the Sault Ste. Marie area (Robinson and Jensen 1980).

their use of the St. Marys River. In lieu of quantitative information, observational records from the river basin will be supplemented with data from the boreal region further north in Ontario.

Passerine birds most closely associated with the St. Marys River include red-winged blackbirds (Agelaius phoeniceus), swamp sparrows (Melospiza georgiana), and tree (Tachycineta bicolor), bank (Riparia riparia), cliff (Hirundo pyrrhonota) and barn (H. rustica) swallows. Red-winged blackbirds nest at the waters edge, usually shoreward of emergent wetlands along the river. These birds rely heavily on emergent wetlands for their food, which consists of insects associated with these wetlands. In the St. Marys River, red-winged blackbirds have been observed walking over floating windrows of Scirpus eating damselfly nymphs (Duffy, pers. observ.). Red-winged blackbirds also feed on emerging damselflies and other aquatic insects (Duffy 1985). Swamp sparrows also feed along the waters edge and nest from the water's edge to alder thickets several hundred meters back from the river.

Over the open water, the most common passerine bird on the St. Marys River is the tree swallow. This species nests in tree holes or cavities in riparian forests and feeds on a variety of insects. On the St. Marys River they appear to feed heavily on emerging chironomids, but quantitative data are lacking. Bank swallows nest where earthen banks provide suitable nesting habitat, such as banks along the Charlotte River, a tributary to the St. Marys River. Cliff swallows nest under the eaves of buildings adjacent to the river, and barn swallows nest in barns or other old buildings. The last three swallows all feed on insects over open fields and wetlands bordering the river and over open water as well.

In addition to the species mentioned, a variety of passerine birds are typical inhabitants of wetlands in the boreal region, which begins around the St. Marys River (Table 49). The richest wetland habitat for birds in the boreal region is riparian habitat which supports a number of species and, collectively, densities of around 300 breeding pairs/km^2 (Erskine 1977). Bogs, while containing a number of species, typically support much lower densities of breeding birds.

A diverse passerine bird community inhabits upland forests in the boreal region (Table 50) and most of these species have been recorded from the St. Marys River area (Weise 1985; Duffy pers. observ.). Factors contributing to this diversity are age, type, and variety of forest vegetation and food resources (Erskine 1977; Welsh 1981). Welsh (1981) found that forest age was a major determinant in passerine bird community composition (Figure 53). Erskine (1977) reported the greatest diversity was often associated with more diverse forest cover, but density was more often related to food and in particular insects. For example, spruce forests with spruce budworm (Choristoneura fumiferna) infestations typically support almost 500 breeding pairs/km^2 while noninfested spruce forests contained from 370-394 pairs/km^2.

Table 49. Characteristic birds of wetland habitats in the boreal region (Erskine 1977).

Common name	Habitat: Bog	Fen	Riparian
Marsh hawk		x	
Sandhill crane		x	
Woodcock			x
Lesser yellowlegs	x	x	
Yellow-bellied sapsucker			x
Eastern kingbird	x		
Eastern wood pewee			x
Olive-sided flycatcher			x
Alder flycatcher	x		
Tree swallow	x		
Gray (Canada) jay	x		
Hermit thrush	x		
Swainson's thrush	x		
Northern water thrush			x
Ruby-crowned kinglet	x		
Parula warbler			x
Mourning warbler			x
Canada warbler			x
Yellow warbler			x
Magnolia warbler	x		
Myrtle warbler	x		
Blackpoll warbler	x		
Palm warbler	x		
Veery			x
Solitary vireo			x
Common yellowthroat	x		
American redstart			x
Purple finch	x		
Northern junco	x		
White-throated sparrow	x		
Lincoln's sparrow	x		
Swamp sparrow	x		
Song sparrow			x
American robin			x

Mammals

The mammalian fauna of the St. Marys River area reflects the region's transitional position at the northern edge of the Great Lakes hardwood and southern edge of the boreal forests. The mammals recorded from the river and its immediate vicinity may be classified into two groups: those whose range extends across the Great Lakes region and others whose range stops in this region. Furthermore, the St. Marys River acts as a "filter-bridge" between southwestern, northwestern, and eastern Appalachian faunal elements (Pruitt 1951). In all, 56 species of mammals have been recorded from the area as well as 3 species formerly occupying the region, but now extirpated. Forty-six are considered here as small mammals and nine are large mammals (Table 51).

Table 50. Characteristic birds of upland habitats in boreal forests (Erskine 1977).

Common name	Habitat: Black spruce	Fir	Hemlock-pine mix	Red, white, pitch pine	Poplar-birch
Ruffed grouse		x			x
Spruce grouse	x				
Northern three-toed woodpecker	x	x			
Yellow-bellied sapsucker					x
Yellow-bellied flycatcher	x	x			
Blue jay		x		x	
Gray (Canada) jay	x				
Black-capped chickadee			x	x	x
Boreal chickadee	x	x			
Brown creeper	x	x			
Winter wren	x	x	x		
Swainson's thrush	x	x	x		
Golden-crowned kinglet	x	x			
Ruby-crowned kinglet	x	x	x		
Least flycatcher					x
Nashville warbler	x	x			
Magnolia warbler	x	x	x		
Myrtle warbler	x	x			
Tennessee warbler		x			
Black-throated green warbler		x	x[a]		
Black-throated blue warbler			x		
Blackburnian warbler		x	x[a]	x	
Black-and-white warbler				x	x
Bay-breasted warbler		x			
Canada warbler					x
Parula warbler			x		
Pine warbler				x	
Ovenbird		x	x[a]	x	x
Veery					x
American redstart		x			x
Slate-colored junco	x	x	x		
Chipping sparrow	x	x			
White-throated sparrow	x	x	x		
Red-breasted nuthatch		x	x[a]	x	
Solitary vireo		x	x[a]		
Red-eyed vireo			x[a]	x	
Purple finch		x			
Rose-breasted grosbeak					x
Brown-headed cowbird				x	
American robin					x

[a]In hemlock alone; others in hemlock mixed with spruce, fir, or pine.

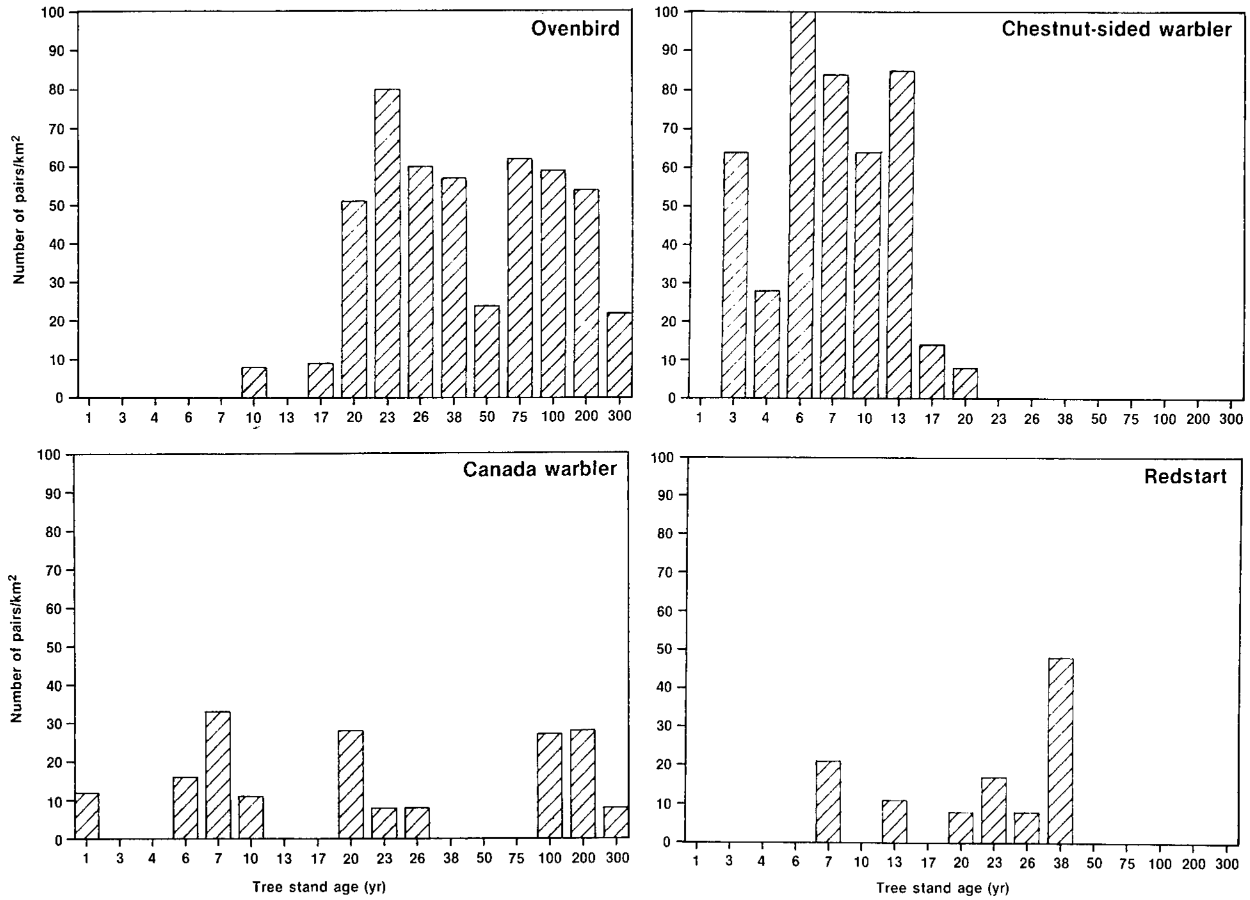


Figure 53. Abundance of selected passerine birds illustrating occurrence as a function of forest age (Welsh 1981).

Small mammals. Small mammals most closely associated with the St. Marys River include beaver (*Castor canadensis*), river otter (*Lutra canadensis*), muskrat (*Ondatra zibethica*), mink (*Mustela vison*), raccoon (*Procyon lotor*), American water shrew (*Sorex palustris hydrobadistes*), and northern water shrew. Although quantitative data are lacking, muskrat are perhaps the most common, and the two species of shrews may also be abundant. However, beaver probably have the greatest influence on the river.

Beaver are anatomically, morphologically, and ethologically more specialized for swimming than any other rodent (Hill 1982). Their size, large hind legs, wide hind feet, flattened tail, type and location of ears, eyes, and nose have enhanced their survival in wetlands. They are found throughout the river, its tributaries, and surrounding wetlands. The preferred food of beaver is poplar and willow; the succulent parts are eaten during the warmer months and bark and cambrium are eaten during the winter (Hill 1982).

Species not intimately associated with the river include a variety of shrews, mice, and voles as well as other small mammals. In upland hardwoods red (*Tamiasciurus hudsonicus*) and gray squirrels (*Sciurus carolinensus*), eastern chipmunks (*Tamius striatus*), deer mice (*Peromyscus maniculatus*), and shorttail shrews (*Blarina brevicauda*) are common (Manville 1949; Duffy, pers. observ.). These species are replaced by red-backed (*Clethrionomys gapperi occidentalis*) and meadow voles (*Microtus pennsylvanicus*), masked shrews (*Sorex cinereus*), snowshoe hares (*Lepus americanus*), and deer mice in spruce and cedar wetlands, while meadow jumping mice (*Zapus hudsonius*) and mink are characteristic of riparian habitats.

Table 51. Mammals observed and potentialy occurring in the St. Marys River and vicinity (Manville 1949, 1950, 1951; Pruitt 1951).

Scientific name	Common name
INSECTIVORA	
Talpidae	
Parascalops breweri	Hairy-tailed mole
Condylura cristata	Star-nosed mole
Scalopus aquaticus	Eastern mole
Soricidae	
Sorex cinereus	Masked shrew
Sorex fumeus	Smoky shrew
Sorex arcticus	Arctic shrew
Sorex palustris	Northern water shrew
Sorex palustris hydrobadistes	American water shrew
Microsorex hoyi	Pygmy shrew
Blarina brevicauda	Shorttail shrew
CHIROPTERA	
Vespertilionidae	
Myotis lucifugus	Little brown myotis
Myotis lucifugus leibii	Small-footed bat
Myotis keeni	Keen myotis
Lasionycteris noctivagans	Silver-haired bat
Eptiesicus fuscus	Big brown bat
Lasiurus borealis	Red bat
Lasiurus cinereus	Hoary bat
CARNIVORA	
Ursidae	
Ursus americanus	Black bear
Procyonidae	
Procyon lotor	Raccoon
Mustelidae	
Martes americana	Marten
Martes pennanti	Fisher
Mustela erminea	Shorttail weasel
Mustela frenata	Longtail weasel
Mustela rixosa	Least weasel
Mustela vison	Mink
Lutra canadensis	River otter
Taxidea taxus	Badger
Mephitis mephitis	Striped skunk
Gulo luscus	Wolverine (vanished)
Canidae	
Vulpes fulva	Red fox, Cross fox
Urocyon cinereoargenteus	Gray fox
Canis latrans	Coyote
Canis lupus	Gray wolf

(Continued)

Table 51. (Concluded).

Scientific name	Common name
CARNIVORA (continued)	
Felidae	
Lynx canadensis	Lynx
Lynx rufus	Bobcat
Felis concolor	Mountain lion (vanished)
RODENTIA	
Sciuridae	
Marmota monax	Woodchuck
Eutamias minimus	Least chipmunk
Tamias striatus	Eastern chipmunk
Tamiasciurus hudsonicus	Red squirrel
Sciurus carolinensis	Eastern gray squirrel (Black squirrel)
Glaucomys sabrinus	Northern flying squirrel
Castoridae	
Castor canadensis	Beaver
Cricetidae	
Peromyscus maniculatus	Deer mouse
Synaptomys cooperi	Southern bog lemming
Phenacomys intermedius	Heather vole
Microtus pennsylvanicus	Meadow vole
Microtus chrotorrhinus	Yellow-nose vole
Clethrionomys gapperi occidentalis	Gapper's red-backed vole
Ondatra zibethica	Muskrat
Muridae	
Rattus norvegicus	Norway rat
Mus musculus	House mouse
Zapodidae	
Zapus hudsonius	Meadow jumping mouse
Napaeozapus insignis	Woodland jumping mouse
Erethizontidae	
Erethizon dorsatum	Porcupine
LAGOMORPHA	
Leporidae	
Lepus americanus	Snowshoe hare
ARTIODACTYLA	
Cervidae	
Odocoileus virginianus	White-tailed deer
Alces alces	Moose
Rangifer caribou	Woodland caribou (vanished)

The small mammal communities of islands within the St. Marys River are similar to the communities of the mainland, with some exceptions (Manville 1950, 1951; Pruitt 1951). On Sugar Island, Pruitt (1949) found the same fauna as in Chippewa County, Michigan, except that bobcats (Lynx rufus), gray squirrels, and raccoons were absent on the island. Drummond Island, which is separated from the mainland by a wider expanse of water than Sugar Island, contained nine fewer species than Chippewa County (Manville 1950). Pruitt (1951) noted that the river acted as a barrier to the distribution of some species, with the arctic shrew (Sorex arcticus), and badger (Taxidea taxus) restricted to the east and gray fox (Urocyon cinereoargenteus), northern flying squirrel (Glaucomys sabrinus), 13-lined ground squirrel (Spermophilus tridecemlineatus), and eastern cottontail rabbit (Sylvilagus floridanus) restricted to the west side. However, badger were reported as occurring on the west side and gray fox on Drummond Island by Manville (1950) and badger have more recently been observed in the Barbeau, Michigan, area (Duffy, pers. observ.).

Large mammals. The distribution and abundance of large mammals in the St. Marys River region characterize the differences between the fauna of mixed boreal forests of Ontario's Algoma District and the northern Great Lakes forest of the Upper Peninsula of Michigan. Moose (Alces alces) are common on the Ontario side of the river but uncommon on the Michigan side. Gray wolves (Canis lupus) and lynx (Lynx canadensis) also are more common in Ontario than in Michigan. In contrast, white-tailed deer (Odocoileus virginianus) and bobcat are more common in Michigan than Ontario, and black bear (Ursus americanus), coyote (Canis latrans), bobcat, and red fox (Vulpes fulva) occur throughout the entire region (Robinson and Fuller 1980). Three species once found in the area have been extirpated: woodland caribou (Rangifer caribou), mountain lion (Felis concolor), and wolverine (Gulo luscus). Woodland caribou apparently inhabited the St. Marys River region until as recently as the early 1900's (Manville 1950) and still inhabit boreal forests northeast of Lake Superior around Wawa, Ontario.

The most common large mammals in the St. Marys River region are white-tailed deer, even though this species is not abundant on the Ontario side of the river. White-tailed deer were absent from this area until around 1850 when they moved into the area through Michigan, then across the St. Marys River into Ontario (Robinson and Fuller 1980). By the early 1900's, white-tailed deer were common throughout the St. Marys River Basin (Figure 54). White-tailed deer range and population size continued to grow with the expansion of logging through the early 20th century. Logging opened the forest canopy and promoted the growth of forbs, shrubs, and saplings, which provided suitable forage for white-tailed deer during this period. Since the 1940's, however, forests have matured and both the range and population size of white-tailed deer have decreased.

In northern climates white-tailed deer gather in "yards" during winter, where

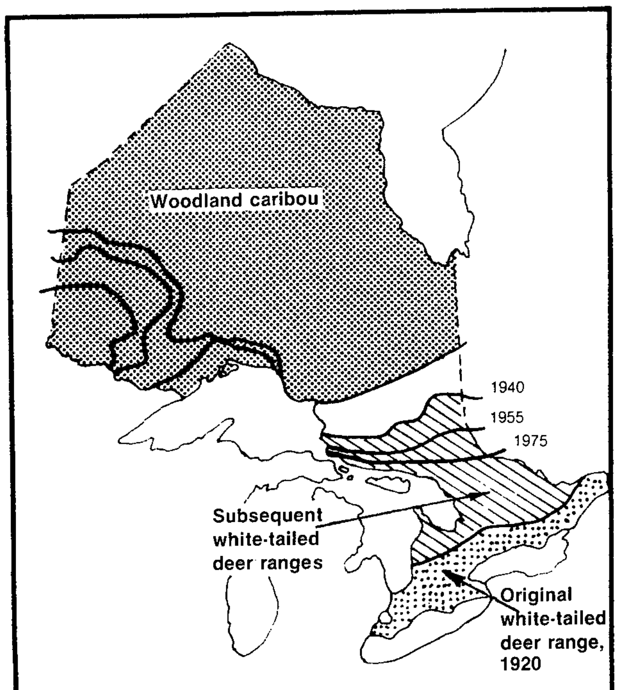


Figure 54. Changes in the white-tailed deer distribution from 1920 to 1975 and current caribou distribution (Smith and Borczon 1977).

suitable browse, typically white cedar, is available; they disperse to summer ranges in spring. Recent studies of white-tailed deer using the St. Marys River estimated that approximately 700 to 1,100 animals wintered in a "deer yard" on Neebish Island and fewer than 100 in another yard northwest of Sault Ste. Marie, Ontario (Robinson and Amacher 1982). Through radio tracking studies Robinson and Amacher (1982) determined that white-tailed deer wintering on southern Neebish Island dispersed to the remainder of this island and to Sugar Island in spring. The distribution of critical white cedar habitats suggests white-tailed deer should be even more abundant in the southern portion of the river (Figure 55). Population information for other portions of the St. Marys River are unavailable. However, Drummond Island has in the past been a productive deer hunting area (see Chapter 5). Observational records suggest the white-tailed deer population of Chippewa County, Michigan, has also remained relatively stable during the past decade (Table 52; Weise 1985b).

North and east of the river, moose become more common than white-tailed deer. Distribution of these two species is related to habitat and forage preferences, but also to disease. White-tailed deer are commonly infested with a clinically silent nematode (*Parelaphostrongylus tenuis*) which causes moose disease (Coady 1982). When moose accidentally ingest the intermediate host snails carrying infected larvae, they develop a neurological disorder usually resulting in death. Because of this, the two species co-occur only in low densities.

An estimated 41 moose occur within 25 km of the St. Marys River (Robinson and

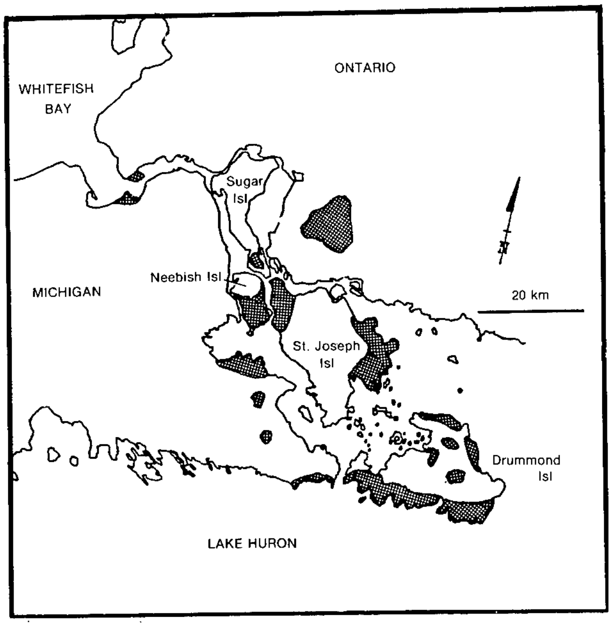


Figure 55. Distribution of white-tailed deer winter yarding areas on island in the St. Marys River and adjacent lands (Robinson and Fuller 1980).

Table 52. Relative abundance of white-tailed deer in Chippewa County, Michigan, during July through October of 1975 through 1983 (Weise 1985b).

Year	Total number observed	Average no/100 hr observation time	Percent			
			Male	Female	Fawn	Unidentified
1975	202	6.1	7.9	34.2	27.7	30.2
1976	329	11.6	9.4	31.9	22.4	36.1
1977	332	9.9	11.1	34.0	18.6	36.1
1978	188	6.2	3.3	34.0	22.3	40.4
1979	102	3.1	7.8	39.2	24.5	28.4
1980	115	5.5	7.8	30.4	14.8	47.8
1981	187	5.6	13.4	39.0	24.1	23.5
1982	122	4.0	14.0	37.0	25.4	23.7
1983	176	5.8	10.8	39.8	21.6	27.8

Fuller 1980). Six of these were found in Michigan, 12-15 on St. Josephs Island, and the remainder on the Ontario mainland. Distributional records indicate that the river is an area of dispersion from higher density areas in Ontario toward Michigan (Figure 56). However, the population size of moose on the Michigan side of the St. Marys River has not increased appreciably since Manville (1950) and Pruitt (1951) surveyed mammals of the region.

Population density of timber or gray wolves in boreal forests is positively related to ungulate (deer and moose) biomass (Figure 57; Keith 1981). However, the presence of people influences wolf population size through disturbance, hunting, and competition for food resources (Robinson and Amacher 1982). These factors combine to limit the population of timber wolves in the vicinity of the St. Marys River relative to areas further north and further east around Algonquin Provincial Park, Ontario (Kolenosky 1981). Timber wolf population size in the vicinity of the St. Marys River was estimated by Robinson and Amacher (1982) to be roughly 18 animals or one wolf/82-114 km^2.

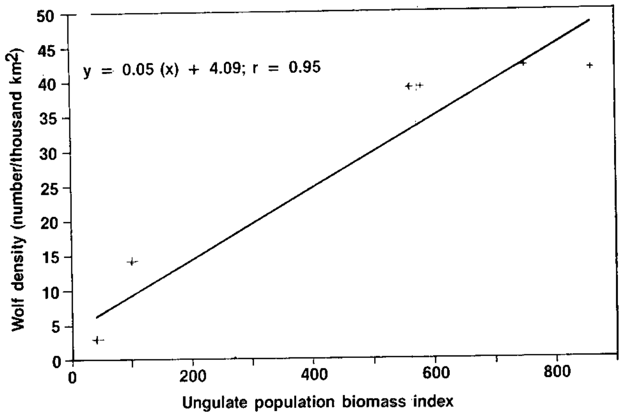


Figure 57. Relationship of wolf densities in seven stationary populations to the total biomass of ungulates present (Keith 1981).

These wolves appeared to be associated with 10 separate packs (Figure 58). Packs VI, VII, and IX were most closely associated with the St. Marys River and frequented deer yards during winter, as did pack X further to the east. Other packs relied on either moose or garbage dumps for winter food resources. The proximity of winter deer yards in Michigan to several wolf packs was suggested as a mechanism which could draw wolves across the river (Robinson and Amacher 1982). One pair of wolves was tracked from a point on southern St. Joseph Island, across Potagannissing Bay and Drummond Island, to Cockburn Island. However, movement of wolves on the river during winter was generally limited.

Other large mammals studied by Robinson and Amacher (1982) were red fox, coyote, bobcat, and lynx. Both coyote and red fox were common and crossed the frozen river more frequently than other large mammals in winter (Fuller and Robinson 1982a). Furthermore, movement of coyote and red fox did not appear to be impeded by ship traffic through ice, although white-tailed deer movement was restricted following ship passages in winter (Fuller and Robinson 1982b).

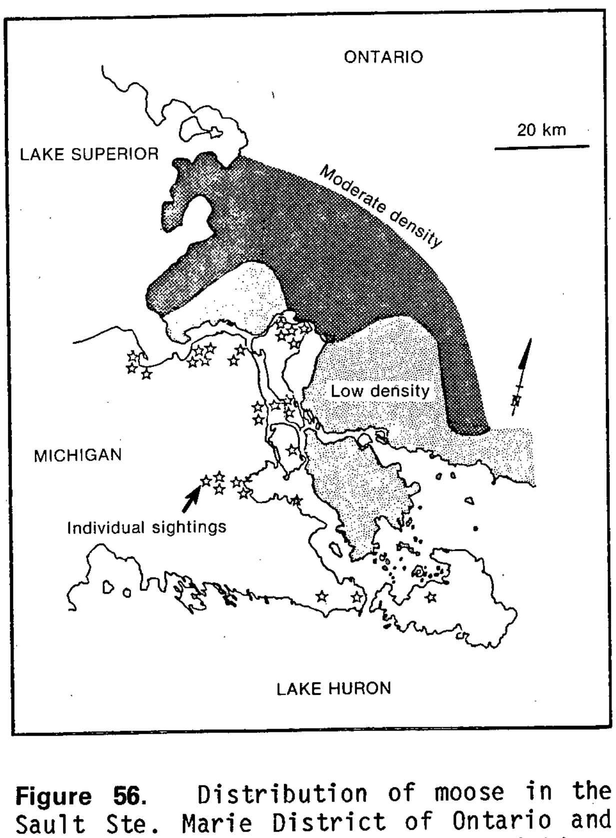


Figure 56. Distribution of moose in the Sault Ste. Marie District of Ontario and the eastern Upper Peninsula of Michigan (Robinson and Fuller 1980.

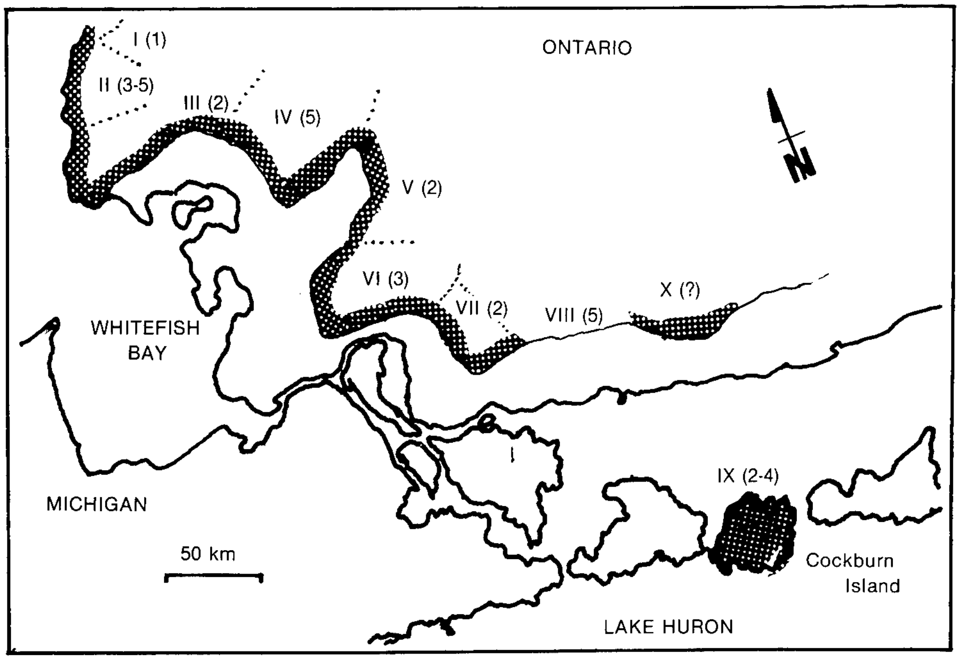


Figure 58. Gray wolf territories in the vicinity of the St. Marys River. Pack number denoted by Roman numerals and approximate size of pack by Arabic numerals (Robinson and Amacher 1982).

CHAPTER 4. ECOLOGICAL RELATIONS

TEMPERATURE AND THE BIOTA

Primary Producers

The St. Marys River has annual water temperature characteristics that are unusual when compared to other North American rivers at the same latitude and continental climate. It lies in a cold system in which rising springtime temperature and maximum summer temperature lag about a month behind most rivers in the temperate zone. In the fall of the year, water in the river is warmer than in its continental counterparts.

Temperature peculiarities of the St. Marys River are inherited from heat-exchange characteristics of water in Lake Superior. Lake Superior water moves rapidly down channels through the length of the river, entraining off-channel water as it goes. Except in backwaters remote from channels, little time is available for water in the river to exchange heat with the atmosphere, and water temperatures in lower reaches differ only a few degrees from those at the head of the river. Reproduction and growth of flora and fauna populations are keyed to water temperature. An example can be taken from the growth of plants that provide food and cover in nursery areas for fish in emergent wetlands.

The effect of temperature on growth of *Scirpus acutus* and *Sparganium eurycarpum* in the shore zone of the St. Marys River is illustrated in Figures 59 and 60. Shoots of these two dominant plants, as well as the secondary dominants *Eleocharis smallii* Britton and *Scirpus americanus*, grow from the base meristems on rootstocks near the surface of the hydrosoils. In Figures 59 and 60, shoot heights of emergent plants are plotted as a function of cumulative degree-days from germination in the spring to maximum biomass later in the growing season (Liston et al. 1986). A degree-day (°d) was taken as $°d = T_d - 7$

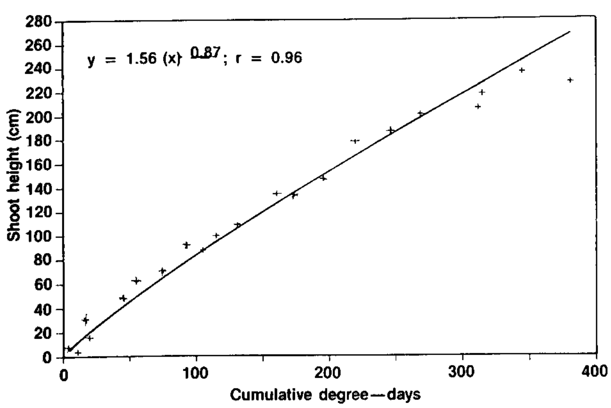


Figure 59. Relationship between mean height of tallest shoots from two separate stands of *Scirpus acutus* and temperature as degree-days above the germination threshold of 7 °C.

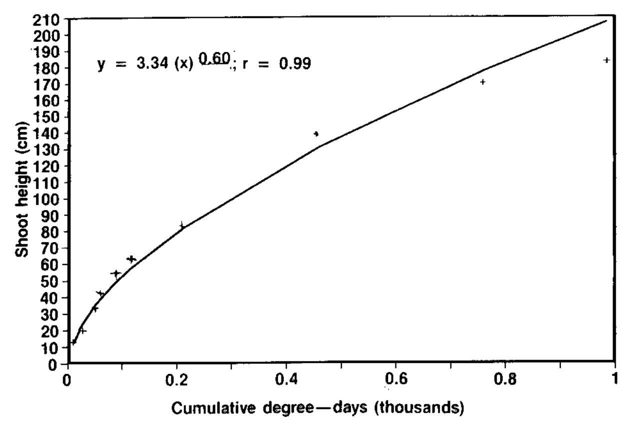


Figure 60. Relationship between mean height of tallest shoots for *Sparganium eurycarpum* and temperature as degree-days above the germination threshold of 7 °C.

where: T_d was the daily mean water temperature (°C) in stands of plants during days in the growing season after germination was initiated, and 7 was the threshold water temperature (°C) for initiating growth of shoots in spring.

Control of emergent plant growth by heat in the environment has several important consequences for casual observers of wetland phenomena and for the scientist making measurements in them. In springtime, as water and hydrosoils in wetlands along the river warm, shoots break the surface of water in a proliferation that spreads from warm shallows at the shores to more slowly warming waters at the outer edge. The speed of this spread depends upon the degree of isolation that wetlands have from cold water meandering across them from adjacent river channels. Liston et al. (1986) have shown that summertime development of wetland vegetation can lag on sites exposed to cold currents, such that cover and maximum annual biomass of dominant species occur several weeks after they are present on warm sites. Time of development of wetland plants similarly differs between years, particularly those of warm versus cold springtimes. Thus, shoots growing in shore-zone wetlands of the St. Marys River in spring and early summer are monitors of temperature regimes. Production of periphyton and invertebrates is keyed to the same temperature regimes.

Secondary Producers

The influence of water temperature on development of invertebrates in emergent wetlands is similar to the relationship observed with macrophytes. The damselfly Lestes disjunctus disjunctus oviposits in stems of Sparganium eurycarpum along the St. Marys River during August; these eggs remain in stems until spring and begin hatching when water temperature exceeds a thermal threshold of 4.3 °C (Duffy 1985). Development of nymphs after hatching is logarithmically related to water temperature as cumulative degree-days (Figure 61). Total physiological time required for L. disjunctus disjunctus to complete nymphal development was 680 and 710 °d in 1982 and 1983, respectively. A similar growth relationship is seen in

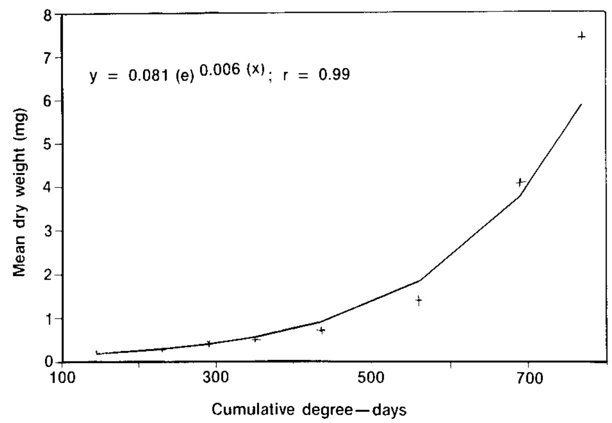


Figure 61. Relationship between mean dry weight of Lestes disjunctus disjunctus and temperature as degree-days above the developmental threshold of 4.3 °C.

another damselfly, Enallagma boreale, and growth of other aquatic invertebrates is also regulated by water temperature.

Invertebrate density in emergent wetlands at ice-out is extremely low. However, warming of these shallow-water environments stimulates the hatching of cladoceran ephippial eggs and eggs from a variety of macroinvertebrates. Cladoceran zooplankton become abundant in emergent wetlands within weeks of ice-out, and with hatching and migration, macroinvertebrates also soon become common. For example, Corixidae migrate into wetlands from ground-water fed tributaries, where they spend the winter. As water temperature continues to increase, both diversity and density of the invertebrate community in emergent wetlands increase.

Fish use of emergent wetlands begins at the time ice is breaking up in spring. Hatching of lake whitefish and lake herring eggs, spawned the previous November, coincides with ice-out in some years. These eggs collect along wetlands or in other backwater areas; larvae have been collected from Lake Nicolet wetlands while slush ice remained along shore (Duffy pers. observ.). Northern pike begin to spawn soon after ice-out, depositing eggs on Carex and other dense aquatic macrophytes near shore. Other spring-spawning species of fish, such as central mudminnow, brown bullhead, bowfin, yellow

perch, and Centrarchidae, also use emergent wetlands. As water temperatures rise, their eggs begin to hatch, and larval development begins in the presence of abundant food resources--the rich microinvertebrate community.

Annual Temperature and Detritus

Organic material from macrophyte production in emergent and submersed wetlands of the St. Marys River becomes food for higher organisms principally through the detrital food web. Muskrats and crayfish are principal grazers of fresh plant material in emergent and submersed wetlands, respectively. At the maximum densities of recent years, they graze a very small fraction of annual plant production in the system: on the order of 1% or less of organic dry weight production (McNabb, unpubl. data).

Ungrazed shoots of emergent plants die back with frost in October-November of each year. They remain in situ and are partially fragmented by freezing and thawing, and by waves. At ice-out and in the month or 6 weeks thereafter, some small fraction of dead shoots is exported into river channels on ice-floes and currents. The majority of overwintering shoot material is trapped in situ by new shoots that break the water surface as springtime progresses. As in offshore submersed wetlands, decomposition of dead shoots from the previous year accelerates with rising water temperatures in May and June. In years of average temperature, shoots are completely fragmented by the end of June and refractory portions join refractory detritus from previous years on the sediment surface. The wetland is thus pulsed in springtime with detritus and the micro-organisms of its decay. McNabb (unpubl. data) estimates conservatively that 60% of annual shoot production is normally mineralized in situ in the month of June: on the average, some 400 g organic dry weight per m^2.

Availability of detritus from plants in submersed charophyte meadows is clearly tied to temperature-regulated metabolic rates of micro-organisms of decomposition (Liston et al. 1986). Biomass in submersed charophyte meadows at the beginning of growing seasons consists largely of degenerating tissue that has overwintered in situ. Micro-organisms of decomposition form a metabolically active periphyton on plants at this time. They, together with detrital fragments of plant origin, constitute a significant food supply for consumer organisms of some 30-35 g organic dry weight per m^2 of meadow. This constitutes a detrital pulse in the system that is mineralized at a temperature-dependent accelerating rate with rising temperature in June. By early August, detritus is virtually absent from charophyte meadows, and fresh plants of the new growing season approach maximum annual biomass. These overwinter to start the cycle anew in the following year.

Thus, the St. Marys ecosystem is pulsed with macrophyte detritus of autochthonous origin in May and June of each year. This detritus is at first concentrated in shore-zone emergent wetlands and in submersed wetlands along the bottom in deeper water. Consumer organisms in these locations experience a peak food availability that will not be repeated for another year. Eventually, material from shore zones and offshore sources is dispersed in downstream environments by currents moving through the wetlands.

FOOD WEBS

Production and Detrital Material

Estimates of annual net primary productivity in the plankton, submersed wetlands, and emergent wetlands of the St. Marys River were given earlier in this ecological profile (Table 16). Measurements for these were made by techniques that yielded production estimates per unit area of habitat. Thus they indicate portions of the system in which primary production is most concentrated, but say little about relative contribution of phytoplankton and macrophytes to primary productivity of the river system as a whole. It is clear, for example, from casual observation of the river, that emergent wetland production, while very high, occurs in an area much smaller than the surface area of open water where relatively low phytoplankton production

occurs. Contributions of emergent wetlands and plankton communities to total primary productivity in the ecosystem, as well as the contribution from submersed wetlands, can be estimated if areas occupied by these community types are known. In this regard, reliable data are available for the broad expanse of the river known as Lake Nicolet (McNabb, unpubl. data); these were used to develop Table 53. Data suggest that relative productivities given in Table 53 for community types likely hold in a general way for broad lake-like portions of the system (not narrow, restricted channels) where mean turbidity in the growing season is low (<8 NTU).[1] In western Munuscong Lake, for example, where submersed wetland development is severely depressed by high turbidity and poor light penetration, submersed plants contribute very little to overall ecosystem production.

Estimates in Table 53 show that rootstocks of emergent plants in shore-zone wetlands of Lake Nicolet have higher annual productivity than other components of the lake's primary production. Some portion of the energy in food reserves stored in rootstocks over the winter is used to initiate shoot development in spring. Rootstock production not used in this manner becomes detritus in upper layers of tightly packed clay sediments in wetlands. Rates at which animals that burrow in the hydrosoil return some fraction of this detritus to the water column are unknown. Observations of hydrosoil cores during growing seasons suggest that rootstock detritus is largely mineralized in situ, with little organic material from rootstock production entering food webs in overlying water.

Shoots of macrophytes in emergent and submersed wetlands are important sources of organic material for consumer organisms of the river. Estimates in Table 53 show that annual production of these is 4 to 10 times greater than annual production of phytoplankton in Lake Nicolet. Measurements in the water column of Lake Nicolet have shown the plankton community to be more heterotrophic in nature than autotrophic; net primary productivity/respiration (P/R) ratios are consistently <1.0 in

[1]NTU = Nephelometric Turbidity Unit.

Table 53. Annual net primary productivity in the Lake Nicolet reach of the St. Marys River (McNabb, unpubl. data).

Community type	Hectares occupied	g AFDW $\cdot$ m^{-2} $\cdot$ yr^{-1}	Metric tons AFDW/yr	Relative productivity[a]
Phytoplankton	3,958	5	198	1
Submersed macrophytes[b]	2,100	35	735	4
Emergent wetlands	298			
Shoots		650	1,940	10
Periphyton		12	36	0.2
Rootstocks		930	2,770	14

[a]Metric tons organic weight (AFDW) per year relative to the phytoplankton.
[b]Periphyton of submersed macrophytes not included: hence, submersed wetland productivity underestimated by an amount due to periphyton. Submersed plants have little periphyton except during decomposition phase in summer.

ice-free seasons (McNabb, unpubl. data). Detrital materials that have their origin in shoot production in emergent and submersed wetlands of the lake, and in similar wetlands upstream, doubtless contribute substantially to the heterotrophic character of the river's plankton community.

Invertebrate consumers play an integral role in processing nutrients which become available through development and senescence of primary producers. Through feeding activities, both zooplankton and macroinvertebrates alter the size of particles in the environment and their surface-to-volume ratio (Wetzel 1983; Merritt et al. 1984). Invertebrates also transform inorganic nutrients into organic matter, which is stored as standing stock biomass available to higher trophic levels. This organic matter may be transferred from one part of the ecosystem to another through drift, emergence of aquatic insects, or other movements. Biomass of aquatic invertebrates is most available to fishes or invertebrate predators (Healey 1984), but amphibians, waterfowl, and shore and passerine birds also feed on invertebrates.

The detrital pulse provided by charophyte meadows during June is likely used by benthic macroinvertebrates. Second-year cohorts of the burrowing mayflies *Hexagenia* and *Ephemera* complete nymphal development in June before emerging in early July. Benthic invertebrate standing crop in portions of the river with higher population densities of these mayflies and other filter-feeding taxa exhibit a rise to seasonal maxima in June (Chapter 3), while standing crop in areas where density of filter feeders is relatively low do not peak in June.

Detrital material resulting from the decomposition of emergent macrophytes during May and June fuels a pulse of invertebrate biomass comprised primarily of zooplankton in emergent wetlands. Standing stock biomass of the two most abundant zooplankton species in these emergent wetlands, *Chydorus sphaericus* and *Acroperus harpae*, increases from May through early July (Duffy 1985). While these species are small, they have rapid development times relative to larger macroinvertebrates.

Estimates of absolute annual invertebrate production for the Lake Nicolet reach exhibit a pattern similar to the pattern of absolute primary production. Production per unit area is less in offshore soft-bottom communities than in emergent wetlands. However, on an aerial basis the soft-bottom benthic community contributes the greatest amount to macroinvertebrate production in Lake Nicolet (Table 54). Similarly, if zooplankton production in the open water were measured, absolute production there could be expected to be far greater than in emergent wetlands because of greater open water area. Organic material articulated as secondary production comprises the food resource of a variety of fishes.

Predator-Prey Interactions

Vertebrate predators can have a profound effect on invertebrate community

Table 54. Annual secondary production in Lake Nicolet (Duffy unpubl. data).

Habitat type	Hectares occupied	Organic weight g dry wt $\cdot$ m^{-2} $\cdot$ yr^{-1}	Metric tons organic wt/yr
Soft bottom benthos	2,647	14.46	382.39
Emergent wetland benthos	298	24.68	73.55
Emergent wetland zooplankton	298	0.56	1.67
Rapids benthos	1	23.68	0.24

composition (Brooks and Dodson 1965; Hall et al. 1970). Furthermore, alterations in aquatic invertebrate community structure have a demonstrated influence on algal community composition and on water quality (Spencer and King 1984). Because both predator and prey communities are dynamic, shifts in trophic relations occur both seasonally and with ontological changes (development) in animals.

Trophic relations of fishes and other animals inhabiting the St. Marys River are depicted in Figure 62. Among the fish species present, four--walleye, yellow perch, northern pike, and white sucker--are considered critical species in percid communities such as the St. Marys River. Walleye and northern pike are primarily piscivorus and potentially influence the remainder of the fish community. Juvenile walleye derive a substantial proportion of their caloric intake from young-of-the-year yellow perch, while adults shift to feed on rainbow smelt, trout-perch, and alewife (Whalen 1980; Sargent 1982; Liston et al. 1986). The only nonfish prey consumed in any number by walleye are burrowing mayflies, which compose more than 50% of the prey items consumed by walleye during midsummer in the St. Marys River (Joyce 1983). Northern pike examined from the river have been almost entirely piscivorus, feeding most heavily on rainbow smelt and spottail shiners (Borgeson 1983).

The diet of white suckers in the St. Marys River has not been studied. However, their inferior mouth and demersal habit suggest benthic feeding. This has been confirmed by a number of studies which report chironomids, mollusks, and cladocerans as important prey (Scott and Crossman 1973). Yellow perch from the river have a varied diet which changes with ontological development (Whalen 1980). Cladocera compose much of the diet

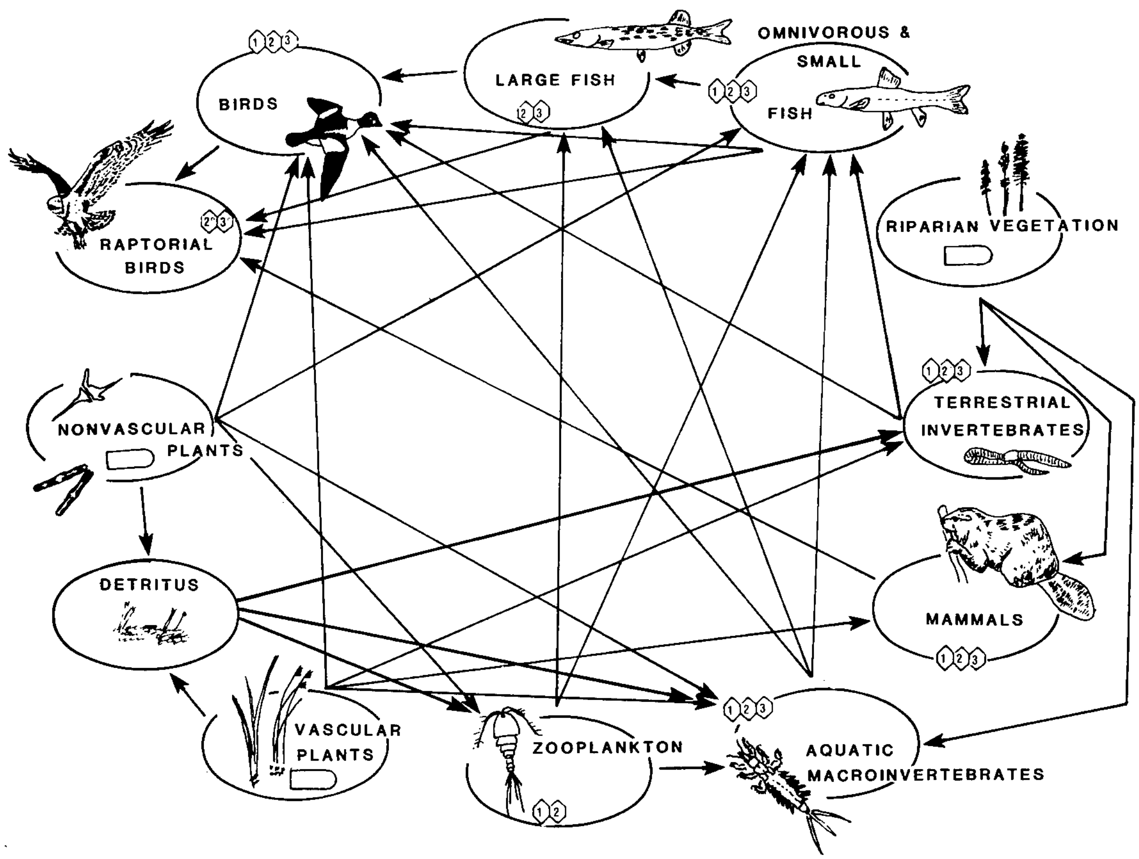


Figure 62. Simplified diagram of energy flow among biotic communities of the St. Marys River.

of juvenile yellow perch 30-60 mm in total length, while fish 80-130 mm long eat more aquatic insects and begin to eat crayfish. Crayfish compose the bulk of the adult yellow perch diet, with fish and burrowing mayflies also important.

Another abundant fish in the open-water habitats of the St. Marys River is the lake herring, a fish listed as threatened in Michigan. Lake herring are pelagic and predominantly zooplanktivorous. In the St. Marys River, zooplankton compose >99% of the diet of lake herring from October through May. However, a mayfly, Leptophlebia, which migrates from deep to shallow water in March is eaten during its migration. Beginning in June, dipteran pupae, Hymenoptera, and burrowing mayfly nymphs are also included in the diet. This diet switches entirely to emerging burrowing mayflies in early July (Figure 63). During a relatively brief 2-week period in midsummer, lake herring ingest >90% of their annual caloric intake from burrowing mayflies (Duffy 1982). Much of this energy is likely not assimilated, but probably constitutes a pulse of energy used in development of gonads prior to spawning in November. Duffy (1982) hypothesized that the decline of lake herring in the Great Lakes may be related more to declining water quality and the disappearance of Hexagenia than to other causes.

Many predators switch to feeding on the mayflies Hexagenia and Ephemera after their mass emergence in the St. Marys River. Normally piscivorus fish, such as walleye and northern pike, feed on the emerging subimagoes, as do yellow perch and rock bass. Common mergansers move into open-water areas after dark to feed on adults returning to the river. Other birds feeding on the adult stages of these mayflies include herring and ring-billed gulls, and black terns. Even dragonflies and damselflies have been observed feeding on adults resting on emergent macrophytes in wetlands (Duffy, pers. observ.).

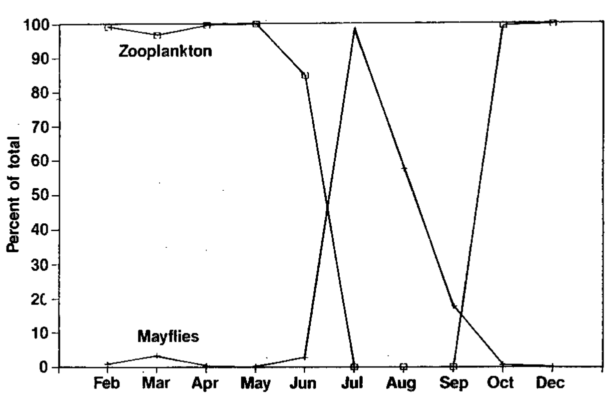


Figure 63. Seasonal composition of lake herring diet in the St. Marys River illustrating dietary switch in July (Duffy, unpubl. data).

Emergent wetlands bordering the main stem of the river are structurally complex. In emergent wetlands, expansive beds of Scirpus acutus and Sparganium eurycarpum are interrupted by pockets of open water containing species of submerged macrophytes; Potamogeton, Ranunculus, and Myriophyllum are common. This heterogeneous environment offers invertebrates and larval and juvenile stages of fish refuge from larger predators. Macrophyte tissues also greatly increase the surface area available for colonization by periphyton. In more protected wetlands the luxurient growths of periphyton which cover these macrophytes in midsummer support dense invertebrate communities. Macroinvertebrates commonly associated with this periphyton include the caddisflie Mystacides and Ceraclea and the mayflies Caenis and Callibaetis (Allard 1982). However, the invertebrate community characteristic of periphyton is numerically dominated by chydorid cladocerans, chironomid larvae, naidid oligochaetes, and ostracods.

The invertebrate community that uses emergent wetland periphyton as a food resource also serves as a food resource for predators. Predation in the emergent wetlands appears to be more diffuse than in open-water habitats, with a variety of predators consuming the invertebrate prey of this environment. Common invertebrate predators of emergent wetlands include damselfly and dragonfly nymphs, dytiscid beetle larvae, some chironomid larvae, and some caddisfly larvae (particularly the genus Polycentropus). Five species of Odonata from the St. Marys River whose diets were examined all consumed chydorid cladocerans, chironomid larvae, ostracods, and smaller caddisfly larvae and mayfly nymphs (Day 1983; Duffy 1984, 1985). These diets overlap widely with the diets

of larval and juvenile yellow perch, bluegill, and rock bass, which along with Cyprinidae are the most common young fish in emergent wetlands. Larvae of each of these fish species feed primarily on cladoceran zooplankton; then as they develop into juvenile stages, they incorporate larger prey, such as chironomid larvae, into their diets.

Larval and juvenile fish predation influences invertebrate community composition and abundance in emergent wetlands. Zooplankton abundance in these wetlands is maximal in June and July, then decreases during August (Figure 64). During July and August, larval fish, particularly bluegill and rock bass, develop into juvenile stages and their diet volume increases. As density of zooplankton decreases in August, juvenile fish begin feeding more on chironomid larvae and other macroinvertebrate taxa (D.E. Ashton, U.S. Army Corps Eng.; New Orleans, Louisiana; pers. comm.). These larval and juvenile fish-invertebrate trophic interactions characterize emergent wetland trophic dynamics of the St. Marys River. However, other predator-prey interactions involving amphibians, birds, and fish also occur.

In May and June red-spotted newts are common in emergent wetlands near the water's edge. These newts feed on caddisfly, chironomid larvae, and other invertebrates found among the dense aquatic macrophytes along shore (Duffy 1982). Great blue herons also forage for juvenile fish in emergent wetlands; unfortunately, quantitative information is lacking on their diet in the St. Marys River. Another colonial waterbird, the black tern, feeds on juvenile and small fish in the emergent wetlands and other shallow-water environments of the river. Black terns can have a devastating impact on juvenile stages of bowfin. Juvenile bowfin school and are heavily pigmented, making them quite visible from the air. Schools remain in densely vegetated areas most of the time, but cross open-water areas when moving from one macrophyte bed to another. At these times black terns often congregate in flocks over a school of young bowfin, diving repeatedly to capture fish (Duffy, pers. observ.).

In addition to these interactions, a number of mammals, birds, and fish use emergent wetlands as foraging habitat (Figure 62). However, trophic interactions of many animals in the St. Marys River have not been studied.

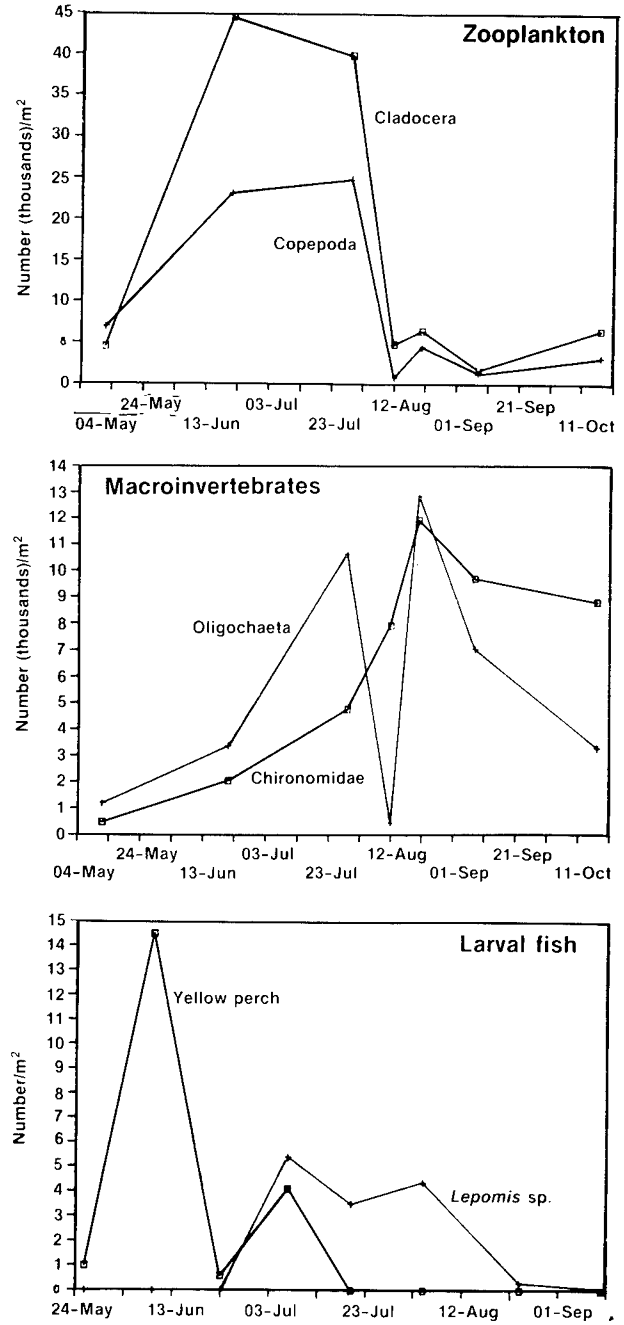


Figure 64. Seasonal abundance of common zooplankton, macroinvertebrates, and larval fish in the Dunbar emergent wetland (Ashton and Duffy, unpubl. data).

CHAPTER 5. MANAGEMENT

COMMERCIAL NAVIGATION

Commercial navigation has had a major influence on the St. Marys River since 1797 and has resulted in extensive modifications of the river (Chapter 1; Table 6). Prior to the 1970's, when most shipping was done during the ice-free period of April through November, there was little concern over the impacts of navigation on this ecosystem. However, during the early 1970's, an increasing demand for continuous transport of goods and materials provided the impetus for a proposed plan of year-round shipping. This meant keeping shipping channels open during periods when the river was normally ice-bound. This raised a great amount of concern as to the potential impact such an action would have on the fish and wildlife of this system (Greenwood et al. 1985).

There are a number of ways commercial shipping influences the St. Marys River, whether ice cover exists or not. Some of these influences are associated with maintenance activities to support shipping, such as dredging, installation of navigation aids, and locks and their operation. Physical phenomena associated with vessel passage also impact the river through alterations in hydrologic patterns. The passage of a vessel through shipping channels or the river temporarily alters the hydrologic pattern in the vicinity of the vessel and, depending on the severity of the hydrologic response, may affect sediment transport, shoreline erosion, or aquatic biota (Upper Mississippi River Basin Commission [UMRBC] 1981).

Hydrologic influences on a point in the river during vessel passage are affected by location of vessels in the river, their draft, speed, and direction of travel with respect to prevailing currents, frequency of passages, bathymetry of the river, and sediment type (UMRBC 1982; Wuebben 1983). A vessel in motion within a river system or constricted channel pushes water ahead of it, lowering water level in the vicinity of midship; a trough is thus created that moves with the ship. The influence of this trough becomes greater as it moves away from the vessel into shallow water, unlike the situation in large, deep water bodies where influence decreases with distance. In addition, a vessel passing through a river or constricted channel forces water to pass beneath its hull at higher speeds than ambient, resulting in changes in pressure on the sediment (Wuebben 1979). As a vessel passes by a point in the river, water level initially rises, then drops, only to rise again as the moving trough of water passes. The height of this wave is related to both vessel speed and velocity of water currents generated by vessel passage (Figures 65, 66). Other factors affecting the hydrologic response to vessel passage are bathymetry of the river, bed-sediment

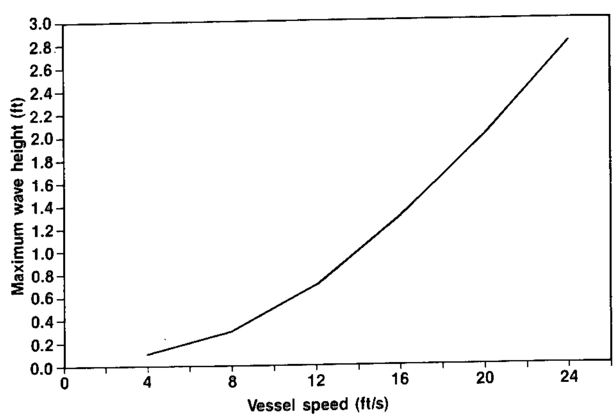


Figure 65. Relationship between maximum wave height and vessel speed at a distance of 100 ft from the shipping line (Ashton 1974).

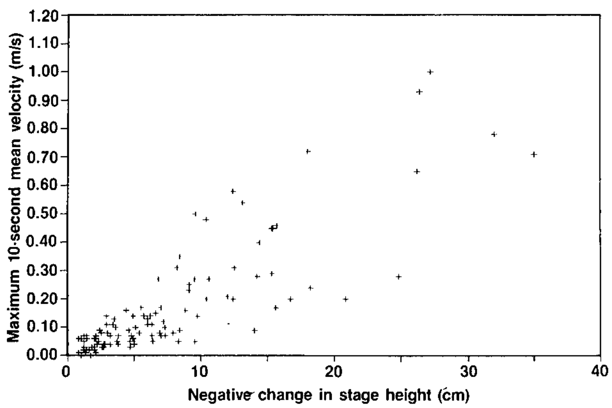


Figure 66. Maximum change in stage height versus maximum 10-second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. (McNabb et al. 1986).

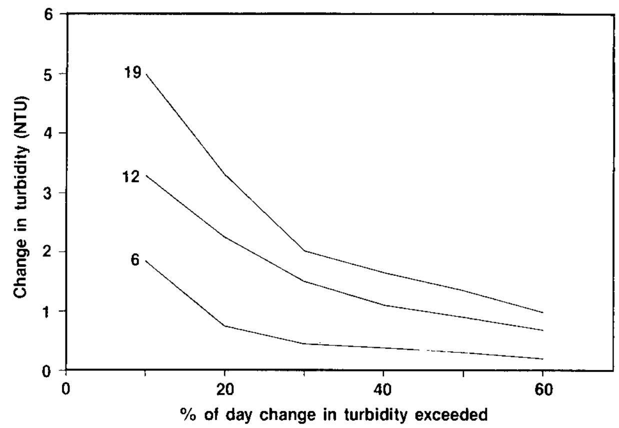


Figure 67. Daily tow induced changes in turbidity levels at low flow (simulated) (UMRBC 1981).

character, and the presence or absence of emergent wetland vegetation (Alger 1978; Wuebben 1983; Smart et al. 1985; McNabb et al. 1986).

Increased sediment transport and shore erosion have been documented as resulting from vessel traffic in the St. Marys River and elsewhere (Alger 1978; Smart et al. 1985). Alger (1978) recorded three modes of sediment transport in the St. Marys River: typical bed load, movement of individual sand grains, and explosive liquefaction. Explosive liquefaction occurs primarily in sand substrate when pressure changes created by the moving trough associated with a vessel reduce effective sediment weight to zero, allowing particles to flow up into the water column (Alger 1978). When this occurs, patches of sediment appear to burst away from the bottom. In the Mississippi River, resuspension of fine sediments and increased turbidity (Figure 67) have been positively correlated with vessel speed and frequency of passage (UMRBC 1981; Smart et al. 1985). The distance sediments are transported following vessel passage is a function of particle size, ambient water currents, and the intensity of hydrologic alterations.

Winter studies on the St. Marys River have addressed the influence of ship traffic on under-ice drift and macroinvertebrate displacement through cracks in ice (Gleason et al. 1979b; Poe and Edsall 1982; Jude et al. 1986). The number of benthic invertebrates, amount of macrophyte material, and biomass of zooplankton and detritus were all greater under ice with ship traffic than without ship traffic (Poe and Edsall 1982). Pressure from vessel-induced waves was found to displace benthic invertebrates up through cracks in ice (Gleason et al. 1979b). However, the number displaced was found to be small in relation to, but representative of, populations existing in the area studied.

In a study of invertebrate populations of emergent wetlands of the St. Marys River, Duffy (1985) reported 18.9% of the mortality of *Lestes disjunctus disjunctus* was attributed to shipping. These damselflies oviposit in stems of *Sparganium eurycarpum* during July and August, but eggs do not hatch until spring. Rising water levels in April 1983 floated broken plant stems away from anchored shoots, allowing vessel-induced currents, such as those measured by McNabb and his colleagues (1986), to pull these floating stems containing eggs out of the emergent wetlands.

The value of emergent wetlands as spawning sites and nursery areas for many species of fish has stimulated interest in the influence of shipping on these habitats. Although Liston (1983, 1986)

documented heavy use of these habitats by larval fish in the St. Marys River, no studies to assess shipping influences have been undertaken. However, laboratory studies have been conducted on the effects of simulated drawdown on eggs and larvae of walleye and northern pike (Holland and Sylvester 1983). In these studies, eggs of neither species were affected by temporary dewatering, but larvae of both species were. Greater mortality of both walleye and northern pike larvae occurred as frequency of drawdowns increased (Figure 68). Holland and Sylvester (1983) suggested that fishes most susceptible to drawdown would be nest-builders such as centrarchids, fishes with adhesive eggs like northern pike, and those with photophobic larvae like walleye.

Small boats operated for recreational purposes may also influence sediment transport and erosion. No studies of recreational boating have been conducted on the St. Marys River. However, in shallow backwater areas of the Mississippi River practically any recreational boat is capable of resuspending fine sediments (Smart et al. 1985). Recreational boats operated in shallow bays or other depositional environments of the St. Marys River probably also resuspend fine sediments, although the impact of this is unknown. Despite the history of navigation and

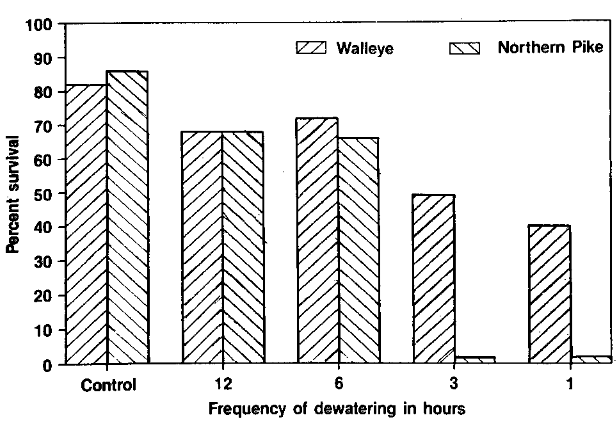


Figure 68. Survival of walleye and northern pike larvae at various intervals of 2-minute exposure to air simulating drawdown with vessel passage (Holland and Sylvester 1981).

associated maintenance activities on the St. Marys River, no attempt has been made to quantify the influence of these maintenance activities on biota. A considerable literature base does exist on the influence of dredging on aquatic biota, as well as limited information for shore birds (Morton 1977; Scharf 1978). Impacts on aquatic biota from dredging are usually classified as either acute or chronic; acute effects include physical removal or burial of benthic species, while chronic effects include a variety of physiological and behavioral responses (Rosenberg and Snow 1975; Morton 1977; Stern and Stickle 1978). Scharf (1978) found that colonial nesting birds used dredge-spoil islands, and that the composition of disposed sediments influenced bird species composition.

Navigation locks present an apparent barrier to fish migration and may also alter water quality. Sparks and Thomas (1978) found suspended particulate matter decreased almost 50% below an Illinois River lock within 8 days of its closure, but they could not separate the influence of the lock discharge from the absence of barge traffic. In areas of reduced water quality navigation lock discharge has been shown to be beneficial by reaerating water low in dissolved oxygen (Wilhelms 1985).

FISHERIES MANAGEMENT

Sound fisheries management should integrate a number of techniques into a program designed to assist the natural fisheries resource decisionmaker. Techniques used should include monitoring of recruitment by stocks or populations, monitoring of both commercial and sport harvest, monitoring the effects of cultural impacts on populations and individuals, and periodic assessment of habitat quality and quantity. Natural resource agencies in both the State of Michigan and Province of Ontario, with support from their respective Federal agencies, have implemented programs which address most of these topics.

Commercial Fisheries

Commercial fishing in the St. Marys River has been phased out since the early

part of the 20th century, although limited subsistence fishing by the Sault Band of the Chippewa Tribe is permitted (Chapter 3). Commercial fishing, primarily for lake whitefish and walleye, is permitted in the North Channel of Lake Huron, which borders the eastern edge of Potagannissing Bay, and in northern Lake Huron. Williamson (1983) suggests that harvest of species which undertake seasonal movements out of the river, such as walleye, yellow perch, and lake herring, could be significant, but the extent of this harvest is at present unknown.

Sport Fisheries

Sportfishing harvests have been periodically monitored since the 1930's by the Michigan Department of Natural Resources and more recently by the Ontario Ministry of Natural Resources. Data from areas of the river excluding the rapids indicate catches declined roughly threefold from the 1930's through the 1970's (Figure 69). Principal fish species harvested by sportfishing are walleye, yellow perch, and northern pike. Additional species of seasonal importance are rainbow smelt and white sucker in spring, lake herring in summer, and chinook salmon in fall. Information from tag and recapture studies of St. Marys River fish indicate sportfishing may be an effective harvest method for selected species over time (Table 55; Liston et al. 1986). Data summarized by Koshinsky and Edwards (1983) indicate average sportfishing catches in the rapids area are roughly 0.1 fish/angler-hour, lower than in the remainder of the river, where catches in recent years have averaged roughly 0.5 fish/angler-hour (Table 56; Figure 69). Principal species of fish harvested from the rapids area are rainbow trout and lake whitefish.

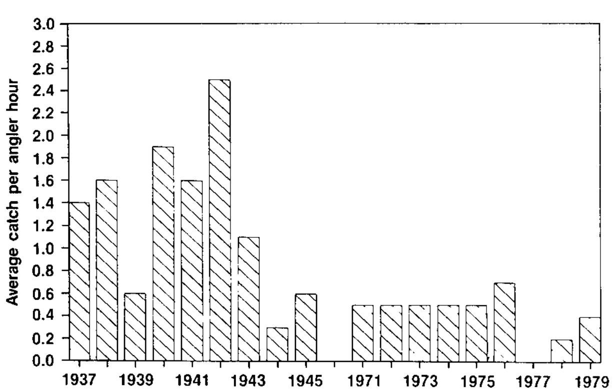


Figure 69. Average catch of fish in the St. Marys River, excluding the rapids, per angler per hour during 1937-45 and 1971-79. (Roelofs 1946; Mich. Dep. Nat. Resour., unpubl. data; Ont. Min. Nat. Resour., unpubl. data).

Table 55. Sportfishing recapture rates during 1982-83 for common fishes of the St. Marys River tagged in 1982 (Liston et al. 1986).

Common name	Recapture rate (%) 1982	1983	Sum
Smallmouth bass	13.6	14.8	28.4
Northern pike	13.4	12.3	25.7
Walleye	2.5	7.0	9.5
Yellow perch	3.4	5.3	8.7
Rock bass	1.3	5.0	6.3
White sucker	0	0.3	0.3
Muskellunge[a]	25.0	0	25.0

[a]Only four individuals tagged.

The Michigan Department of Natural Resources estimates that, overall, the St. Marys River accounted for roughly 110,000 angler-days of sportfishing annually (Koshinsky and Edwards 1983). Approximately 20% of this activity was estimated to be related to the stocking of Pacific salmon and trout, with the remainder directed towards native species. Based on these estimates and estimates of the value of an angler-day at $25, the value of the St. Marys River sport fishery to Michigan anglers is approximately $2.5 million dollars annually. Sportfishing data for the Ontario side of the river suggest that approximately 10,000 angler-days may be attributed to the rapids area annually, but information for the remainder of the river is not available.

Historically, data such as those mentioned above gathered State- and Provincewide have been used to evaluate and manage fish populations, primarily through catch

Table 56. Summary of creel census data from the Ontario side of the St. Marys Rapids, 1971-82 (Koshinsky and Edwards 1983).

	Year					
	1971 May-Oct	1972 May-Aug	1976 May-Aug	1977 May-Aug	1977 Aug-Nov	1982 May-Sep
Angler hours		19,971	10,252	11,391	3,700	16,818
Total catch (No.)		1,361	885	797	407	1,740
Catch per hour		0.07	0.09	0.07	0.11	0.10
	Percent of total catch					
Rainbow trout	14	41	21	56	48	16
Lake whitefish	38	47	46	13	3	68
Other salmonids	5	4	11	13	36	11
Other fish	43	8	22	18	13	5

quotas, license fees, and stocking programs (Figure 70). More recently, body burdens of toxic substances have been used in recommending levels of consumption of fish. However, with certain exceptions, the value of different habitats to fish has generally not been quantified or used in management programs until recently. An exception to this is the St. Marys Rapids where the amount of water flow is critical to the amount of fish habitat. Here, the area of rapids inundated under various flow regimes has been quantified and used

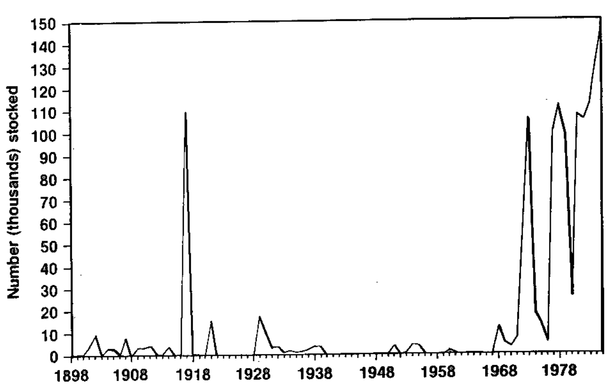


Figure 70. Number of rainbow/steelhead trout and chinook salmon stocked in the St. Marks River by the Michigan Department of Natural Resources during 1898-1985 (Mich. Dep. Nat. Resour., unpubl. data).

in developing water-use policies which would minimize impacts to fishery resources (Koshinsky and Edwards 1983).

Exotic Species

The introduction of exotic fish species into the Great Lakes ecosystem has altered community composition of both fish and their prey and confronted fishery resource managers with often difficult problems. Much of the fish biomass now present in the Great Lakes is represented by exotic species. They were introduced either intentionally or accidentally, or they invaded the lakes through their connection with the Atlantic Ocean. The most notorious of these exotic species are alewife and sea lamprey.

In the St. Marys River, the exotic species of most concern is the sea lamprey. Unlike other species which have made their way into the Great Lakes, sea lamprey are parasitic and attack larger species of fish (Chapter 3). Sea lamprey are of special concern in the St. Marys River not only because the river offers habitat for spawning and ammocoete development, but more importantly because the river is too large to be treated with the chemicals used to control sea lamprey in smaller tributary streams (Daugherty et al. 1984; Daugherty and Purvis 1985). At present,

sea lamprey spawning in the St. Marys River appear to be contributing substantially to the Lake Huron population (Daugherty et al. 1984).

While sea lamprey have had a negative effect on fisheries of the Great Lakes, other exotic species have provided additional fishery resources. Rainbow smelt eggs were intentionally introduced into the St. Marys River during the early 1900's, but apparently did not survive (Koshinsky and Edwards 1983). Later, an accidental introduction of rainbow smelt into northern Lake Michigan (Scott and Crossman 1973) served to populate the entire Upper Great Lakes, and rainbow smelt now represent a limited spring sport fishery in some tributaries of the St. Marys River. Coho and chinook salmon, successfully introduced to Lake Michigan in the 1960's, now provide both an open water and riverine sport fishery in the Great Lakes.

Alewife were first reported from the Great Lakes in collections from Lake Ontario in 1873 (Scott and Crossman 1973). They became abundant in Lake Ontario by the late 1800's, began dispersing to other lakes in the early 1900's, and by 1949 inhabited all of the Great Lakes. Population increases during the 1950's were followed by massive dieoffs of alewives during the 1960's. During this period alewife dieoffs plagued beaches and harbors from Toronto to Chicago. The introduction of top predators such as Pacific salmon beginning in the late 1960's and to a lesser extent the rejuvenation of lake trout populations and the commercial harvest of alewife have since reduced populations below former nuisance levels. In the St. Marys River, alewife are seasonally common but not abundant.

WILDLIFE MANAGEMENT

Wildlife management practices rely on information similar to that used by fisheries managers. However, wildlife management practices have tended to place greater emphasis on habitat considerations than fisheries management, perhaps because terrestrial habitat is more easily quantified. Wildlife data collected by both State and Provincial natural resource agencies are, in general, difficult to relate directly to the St. Marys River ecosystem. Census data often cover wide geographic areas of which the river may be a small part. Other animals are seasonally mobile and may use the river for short periods of time. The exception to this generalization is waterfowl, for which some data from the St. Marys River exist.

Several important waterfowl hunting areas are located within the St. Marys River ecosystem. These include Pumpkin Point Marsh and Echo Bay on the east (Ontario) side of Lake George and Munuscong Lake. Ceolin (1980) estimated that hunters harvested 1,093 migratory waterfowl from Pumpkin Point Marsh during almost 2,700 hours in the 1979-80 Ontario hunting season. Site-specific information on waterfowl harvest from the Michigan side of the river is not available, though Jaworski and Raphael (1978) do report an annual average of 5,214 ducks harvested in Chippewa County, Michigan, during 1961-70. If harvest success estimates for Chippewa County are similar to those reported by Ceolin (1980), it can be estimated that roughly 12,700 hours were devoted to waterfowl hunting annually, with much of this probably along the St. Marys River. The value of Michigan's marshes along the St. Marys River for waterfowl hunting was estimated to be $374,000 annually (Jawarski and Raphael 1978; Raphael and Jaworski 1979). Principal species harvested in early fall are mallard and ringneck ducks, with scaup becoming the principal species in late October and November (Ceolin 1980; Weise 1985a).

Riparian areas adjacent to the river also support populations of big and small game animals and furbearing mammals which are harvested by sport hunters and trappers. Whitetail deer and black bear are harvested on both sides of the river, moose on the Ontario side only. In Ontario, whitetail deer are less common than in Michigan and a greater proportion of big game hunting effort is directed toward moose. Principal small game animals harvested from the river basin are ruffed grouse and snowshoe hare (Ont. Min. Nat. Resour. 1980; Mich. DNR 1985).

White-tailed deer harvest records from Drummond Island provide the best information relating harvest of game animals directly to the river (Figure 71). These data illustrate a general increase in the number of hunters from 1935 through 1968. During the same period, the number of whitetail deer harvested was cyclical, with peaks in harvests occurring at 5- to 10-year intervals. However, since the late 1960's when the maximum number of hunters on the island was recorded, both deer harvested and number of hunters have declined. On larger St. Joseph Island, Ontario, only 55 whitetail deer were harvested by 525 hunters in 1978 (Ont. Min. Nat. Resour. 1980).

Moose harvest records from the Ontario Ministry of Natural Resources (1980) indicate fewer moose are killed in the south portion of the Sault Ste. Marie District bordering the St. Marys River than in the north half. In the south half of the district 296 moose were killed, representing a 55% harvest level in 1979. However, harvest rates were higher than average around Gros Cap and the Garden River bordering the St. Marys River. In the north half of the district the 424 moose killed represented a 25% harvest level for 1979.

Quantitative data for other game species are either lacking or not specific to the area bordering the river. The

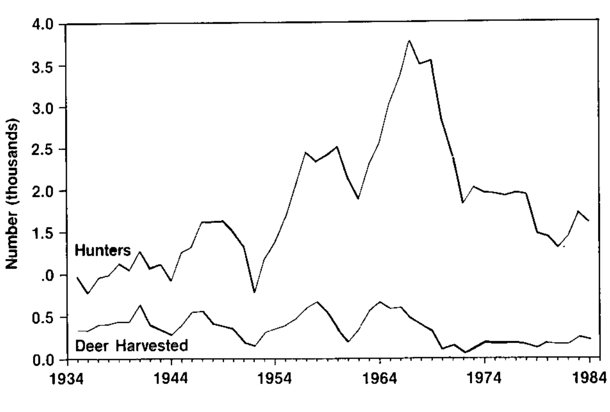


Figure 71. Number of hunters on and white-tailed deer harvested from Drummond Island, Michigan, from 1935 through 1983 (Mich. Dep. Nat. Resour., unpubl. data).

Michigan Department of Natural Resources (1985) reports from 35,110 to 45,120 hunters annually in the Upper Peninsula of Michigan pursuing ruffed grouse during the period 1979-83. Snowshoe hare and woodcock were the next most commonly sought species. These are also the most commonly hunted species in the Sault Ste. Marie District of Ontario (Ont. Min. Nat. Resour. 1980).

Furbearing mammals collected from the area around the St. Marys River are presented in Table 57. The most commonly collected species in both Michigan and Ontario is beaver, with mink, muskrat, and otter also common. Marten (Martes americana), fisher (M. pennanti), and lynx are harvested in Ontario (Table 57), but protected in Michigan. Trapping represents a small industry on both sides of the river. Total value of furs collected from the Upper Peninsula of Michigan ranged from $4.5 to $8.6 million annually during 1981 through 1984, and totaled roughly $100,000 in the Sault Ste. Marie District of Ontario in 1979.

WETLAND MANAGEMENT

During the last century, biological resources of the St. Marys River have been influenced by the activities associated with the region's expanding populations and commerce (Chapter 1). In response to the intensified use of the river system accompanying these activities, a number of statutes have been enacted by governments to manage biological resources in the public interest. Three statutes of the State of Michigan are particularly important for the protection of the primary food production and nursery areas for fish and wildlife resources, and particularly for the emergent wetlands.

The Great Lakes Submerged Lands Act of 1955 established a fixed elevation, the ordinary high-water mark, below which alterations of the shore zone, including wetlands of the St. Marys River, are regulated. The Shorelands Protection and Management Act of 1970 mandates the State Department of Natural Resources to regulate use and development within three types of sensitive coastal areas:

Table 57. Number of furbearing mammals collected and reported by trappers in the eastern Upper Peninsula of Michigan (numbers in parentheses are for Chippewa County only) and the Sault Ste. Marie District of Ontario (Ont. Min. Nat. Resour. 1980; Mich. Dep. Nat. Resour. 1985).

Year	Michigan				
	Otter	Muskrat	Bobcat	Beaver	Mink
1975	91	184	n.d.	n.d.	n.d.
1976	127	222	n.d.	n.d.	n.d.
1977	143	240	(28)	(1,168)	n.d.
1978	111	171	(45)	(681)	n.d.
1979	90	230	(47)	(771)	n.d.
1980	167	677	(73)	(2,571)	n.d.
1981	101	181	(30)	(1,239)	140
1982	51	24	(20)	(599)	378
1983	124	182	(11)	(2,569)	227
1984	89	174	(25)	(1,260)	378
	Canada				
	Otter	Marten	Lynx	Fisher	Mink
1978-79	94	994	6	1	287

high-risk erosion, flood-risk, and environmental areas. Sensitive environmental areas are those considered necessary for preservation and maintenance of fish and wildlife resources of the Great Lakes and their connecting channels. Emergent wetlands along and adjacent to the shore of the St. Marys River have been designated as sensitive environmental areas under this act. At the time of this writing, some 55 km of shoreline along the main channel of the river in Michigan have been so designated. The Wetland Protection Act of 1979 more broadly regulates alteration of wetlands in the State as a whole, including those of the St. Marys River. It is clear from these examples, and other U.S. Federal and Canadian legislation of similar intent, that a framework is in place by which emergent wetlands of the St. Marys River system can be preserved and managed as biological resource production areas. The legislation should be applied to the extensive submersed wetlands of the river as well. Like their emergent counterparts, they are also essential for production of fish and wildlife resources and sediment stabilization.

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16. Abstract (Limit: 200 words)
St. Marys River, the single outlet from Lake Superior, flows between Michigan and Ontario and has formed the International Border between the United States and Canada since 1783. Although the riverbed and a major rapids system have been modified to accommodate commercial navigation and for hydroelectric generation, the St. Marys River retains more of its biological and physiochemical integrity than any other Laurentian Great Lakes connecting channel. This oligotrophic lake's cold, well-oxygenated water contributes >90% of the river's annual flow and has a major influence on the evolution of its biological communities. This monograph reviews the published and unpublished ecological information available for the St. Marys River. The authors begin by reviewing the geologic history, human exploration, and settlement of the region, then proceed to a description of the physical and chemical characteristics of the river. The third chapter describes the biological communities presently inhabiting the river. A fourth chapter synthesizes ecological relationships within the river, emphasizing detrital food webs and trophic interactions. In the final chapter, anthropogenic influences on the river ecosystem are reviewed and various natural resource management strategies suggested.

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